

DEVELOPMENT OF NEW PEDESTRIAN CROSSING GUIDELINES IN UTAH

Final Report

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Abstract

Example pedestrian crossing guidelines relating to 21 different pedestrian safety issues are presented. The research team identified the 21 issues through a study of 294 pedestrian-vehicle collision sites in Utah. The example guidelines address pedestrian crossing facilities and enhancements, pedestrian signals, pedestrian facilities, conflicts between pedestrians and turning vehicles, measures and strategies targeted at drivers, pedestrian volume data collection and usage, pedestrian visibility enhancement, and child pedestrians. The emphasis of the example guidance is on engineering-related strategies. The strategies were selected to mitigate the identified pedestrian safety issues. Most of the techniques were obtained from a review of actions taken and tested in Portland (Oregon), Florida, New Jersey, Washington and Salt Lake City (Utah), and as reported in the literature. Example guidance is provided for pedestrian crossings adjacent bus stops, where to mark crosswalks, pedestrian refuges, crosswalk enhancements, signing, pedestrian signal timing and maintenance, countdown pedestrian indicators, sidewalk construction, grade-separated pedestrian crossings, advance warning pavement markings for drivers, guidance and pavement markings for pedestrians, lighting, and traffic calming in neighborhoods. Further study is needed of pedestrian crossing flags, the incorporation of pedestrians into all-red clearance interval calculations, gap-actuated pedestrian signals, pushbutton exclusion, leading pedestrian indicators, and driver penalties following collisions with pedestrians. Extensive before-after studies of the various example treatments are needed to determine their effectiveness. A better understanding of pedestrian characteristics and volumes would facilitate the selection of mitigating approaches. The report includes summaries of pedestrian-related policies, recommendations and regulations in the MUTCD and in the Utah Administrative Code. A companion document offers detailed information on pedestrian-vehicle collisions and crash sites in Utah.

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CHAPTER 1.0 Introduction and Overview

1.1 Purpose of this Document

This report contains example guidelines for pedestrian crossings in Utah. The examples are not intended to be recommendations; the examples are meant to be a resource for the Utah Department of Transportation (UDOT) as pedestrian safety strategies are considered. That is, this document is to serve as an informational tool in the development of new pedestrian crossing guidelines in the State. Some example guidelines are accompanied by a list of sites at which implementation might be considered. The example guidance has been developed through a review of the literature. Also considered are the actions of several agencies that have been innovative in their approaches to pedestrian safety; the agencies include the city of Portland, Oregon, and the states of Florida, New Jersey and Washington. The pedestrian safety actions of Salt Lake City, which have been similarly aggressive and inventive, are also considered. The example guidelines do not address educational, enforcement, behavioral, or vehicular design interventions. The guidelines emphasize engineering-related strategies. It must be recognized, though, that driver and pedestrian behavior are essential ingredients in pedestrian safety. In a similar vein, vehicular design improvements are essential to reducing the severity of pedestrian injuries. Education, however, may be the most critical component in the effort to improve pedestrian safety.

1.2 Summary of the MUTCD's Pedestrian-Related Recommendations

Current UDOT policy on pedestrian crossings incorporates the *Manual on Uniform Traffic Control Devices (MUTCD 2003)*, which offers guidance and recommendations on pedestrian signal needs studies, pedestrian signal control features, crosswalk markings, yield and stop lines in advance of crosswalks, pedestrian-oriented signing, and school zone warnings and controls. The MUTCD describes eight warrants for traffic signals, two of which consider pedestrians. Warrant 4 considers pedestrian volumes, while Warrant 5 addresses school crossings. The following material is excerpted from the MUTCD:

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that both of the following criteria are met:

- A. The pedestrian volume crossing the major street at an intersection or midblock location during an average day is 100 or more for each of any 4 hours or 190 or more during any 1 hour; and
- B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic.

The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads conforming to requirements set forth in [Chapter 4E](#).

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

- A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
- B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
- C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Option:

The criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 1.2 m/sec (4 ft/sec).

A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street, even if the rate of gap occurrence is less than one per minute.

Section 4C.06 Warrant 5, School Crossing**Support:**

The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (see [Section 7A.03](#)) and there are a minimum of 20 students during the highest crossing hour.

Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.

The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

- A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
- B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
- C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

If pedestrian or school crossing volumes meet the preceding warrants, then signalization is recommended. A marked crossing would generally be provided in conjunction with the signal. Because the minimum pedestrian volumes in Warrant 4 are quite high, the criteria may be satisfied at only a limited number of locations. A side issue is that the data needed to apply the warrant are often unavailable. Pedestrian signal control features are given an extensive discussion in the MUTCD, as follows:

Section 4E.01 Pedestrian Signal Heads

Support:

Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

Guidance:

Engineering judgment should determine the need for separate pedestrian signal heads (see [Section 4D.03](#)) and accessible pedestrian signals (see [Section 4E.06](#)).

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

Pedestrian signal head indications shall have the following meanings:

- A. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the WALKING PERSON (symbolizing WALK) signal indication is first shown.
- B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed out of the traveled way.
- C. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.
- D. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:

- A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see [Chapter 4C](#));
- B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped; or
- C. At an established school crossing at any signalized location.
- D. Where engineering judgment determines that multiphase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.

Guidance:

Pedestrian signal heads should be used under any of the following conditions:

- A. If it is necessary to assist pedestrians in making a reasonably safe crossing or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;
- B. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval; and/or
- C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting or continuing a crossing provide insufficient guidance for them to decide when it is reasonably safe to cross, such as on one-way streets, at T-intersections, or at multiphase signal operations.

Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications

Standard:

All new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages may be retained for the remainder of their useful service life. The symbol designs that are set forth in the "Standard Highway Signs" book shall be used. Each pedestrian signal head indication shall be independently illuminated and emit a single color.

Figure 4E-1 Typical Pedestrian Signal Indications



The UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above or integral with the WALKING PERSON (symbolizing WALK) signal section.

The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see [Section 1A.11](#)), with all except the symbol obscured by an opaque material.

The UPRAISED HAND (symbolizing DONT WALK) signal indication shall be Portland orange, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see [Section 1A.11](#)), with all except the symbol obscured by an opaque material.

When not illuminated, the WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK) symbols shall not be readily visible to pedestrians at the far end of the crosswalk that the pedestrian signal head indications control.

For pedestrian signal head indications, the symbols shall be at least 150 mm (6 in) high.

The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.

Guidance:

Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m (10 ft) from the end of the controlled crosswalk during both day and night.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the pedestrian signal head indications, the symbols should be at least 225 mm (9 in) high.

Option:

An animated eyes symbol may be added to a pedestrian signal head in order to prompt pedestrians to look for vehicles in the intersection during the time that the WALK signal indication is displayed.

Standard:

If used, the animated eyes symbol shall consist of an outline of a pair of white steadily-illuminated eyes with white eyeballs that scan from side to side at a rate of approximately once per second. The animated eyes symbol shall be at least 300 mm (12 in) wide with each eye having a width of at least 125 mm (5 in) and a height of at least 62 mm (2.5 in). The animated eyes symbol shall be illuminated at the start of the walk interval and shall terminate at the end of the walk interval.

Section 4E.05 Location and Height of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 2.1 m (7 ft) nor more than 3 m (10 ft) above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.

If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them.

Section 4E.06 Accessible Pedestrian Signals

Support:

The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, corresponding to the onset of the green interval. This technique is effective at many signalized locations. The existing environment is often sufficient to provide the information that pedestrians who have visual disabilities need to operate reasonably safe at a signalized location. Therefore, many signalized locations will not require any accessible pedestrian signals.

Guidance:

If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross reasonably safe and effectively, an engineering study should be conducted that considers the safety and effectiveness for pedestrians in general, as well as the information needs of pedestrians with visual disabilities.

Support:

The factors that might make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right-turn movements, complex signal operations, traffic circles, and wide streets. Further, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

Local organizations, providing support services to pedestrians who have visual and/or hearing disabilities, can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board's Document A-37, "Accessible Pedestrian Signals," provides various techniques for making pedestrian signal information available to persons with visual disabilities (see [Addresses](#) for the address for the U.S. Access Board).

Accessible pedestrian signals provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Information regarding detectors for accessible pedestrian signals is found in [Section 4E.09](#).

Standard:

When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.

Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.

Guidance:

The installation of accessible pedestrian signals at signalized locations should be based on an engineering study, which should consider the following factors:

- A. Potential demand for accessible pedestrian signals;
- B. A request for accessible pedestrian signals;
- C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
- D. The complexity of traffic signal phasing; and
- E. The complexity of intersection geometry.

Support:

Technology that provides different sounds for each nonconcurrent signal phase has frequently been found to provide ambiguous information.

Standard:

When choosing audible tones, possible extraneous sources of sounds (such as wind, rain, vehicle back-up warnings, or birds) shall be considered in order to eliminate potential confusion to pedestrians who have visual disabilities.

Guidance:

Audible pedestrian tones should be carefully selected to avoid misleading pedestrians who have visual disabilities when the following conditions exist:

- A. Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.
- B. Where multileg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.
- C. At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.

Standard:

When accessible pedestrian signals have an audible tone(s), they shall have a tone for the walk interval. The audible tone(s) shall be audible from the beginning of the associated crosswalk. If the tone for the walk interval is similar to the pushbutton locator tone, the walk interval tone shall have a faster repetition rate than the associated pushbutton locator tone.

Support:

A pushbutton locator tone is a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing, and that enables visually impaired pedestrians to locate the pushbutton (see [Section 4E.09](#)).

Guidance:

The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase.

Automatic volume adjustment in response to ambient traffic sound level should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound. The A-weighted sound pressure level should conform to the requirements of “ISO 1996-1:1982” and “ISO 1996-2:1987” (see [Addresses](#) for the address for the International Organization for Standards).

Standard:

When verbal messages are used to communicate the pedestrian interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies.

The verbal message that is provided at regular intervals throughout the timing of the walk interval shall be the term "walk sign," which may be followed by the name of the street to be crossed.

A verbal message is not required at times when the walk interval is not timing, but, if provided:

- A. It shall be the term "wait."
- B. It need not be repeated for the entire time that the walk interval is not timing.

Option:

Accessible pedestrian signals that provide verbal messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

Support:

A vibrotactile pedestrian device communicates information about pedestrian timing through a vibrating surface by touch.

Standard:

Vibrotactile pedestrian devices, where used, shall indicate that the walk interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means.

Guidance:

When provided, vibrotactile pedestrian devices should be located next to, and on the same pole as, the pedestrian pushbutton, if any, and adjacent to the intended crosswalk.

Section 4E.07 Countdown Pedestrian Signals**Option:**

A pedestrian interval countdown display may be added to a pedestrian signal head in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.

Standard:

If used, countdown pedestrian signals shall consist of Portland orange numbers that are at least 150 mm (6 in) in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication.

If used, the display of the number of remaining seconds shall begin only at the beginning of the pedestrian change interval. After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.

If used, the countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval. Countdown displays shall not be used during the walk interval nor during the yellow change interval of a concurrent vehicular phase.

Guidance:

If used with a pedestrian signal head that does not have a concurrent vehicular phase, the pedestrian change interval (flashing UPRAISED HAND) should be set to be approximately 4 seconds less than the required pedestrian crossing time (see [Section 4E.10](#)) and an additional clearance interval (during which steady UPRAISED HAND is displayed) should be provided prior to the start of the conflicting vehicular phase. In this case, the countdown display of the number of remaining seconds should be displayed only during the display of the flashing UPRAISED HAND, should display zero at the time when the flashing UPRAISED HAND changes to steady UPRAISED HAND, and should be dark during the additional clearance interval prior to the conflicting vehicular phase.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the countdown pedestrian signal display, the numbers should be at least 225 mm (9 in) in height.

Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.

If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see [Section 4E.10](#)), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.

Section 4E.08 Pedestrian Detectors

Guidance:

When pedestrian actuation is used, pedestrian pushbutton detectors should be capable of easy activation and conveniently located near each end of the crosswalks.

Standard:

Signs (see [Section 2B.44](#)) shall be mounted adjacent to or integral with pedestrian pushbutton detectors, explaining their purpose and use.

Option:

At certain locations, a sign in a more visible location may be used to call attention to the pedestrian detector.

Guidance:

If two crosswalks, oriented in different directions, end at or near the same location, the positioning of pedestrian detectors and/or the legends on the pedestrian detector signs should clearly indicate which crosswalk signal is actuated by each pedestrian detector.

Standard:

If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector shall be provided in the median.

Guidance:

The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.

A mounting height of approximately 1.1 m (3.5 ft) above the sidewalk should be used for pedestrian pushbutton detectors.

If used, special purpose pushbuttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.

Standard:

If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, it shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.

Option:

At signalized locations with a demonstrated need and subject to equipment capabilities, pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Section 4E.09 Accessible Pedestrian Signal Detectors

Standard:

An accessible pedestrian signal detector shall be defined as a device designated to assist the pedestrian who has visual or physical disabilities in activating the pedestrian phase.

At accessible pedestrian signal locations with pedestrian actuation, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.

Option:

Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

Pushbutton locator tones may be used with accessible pedestrian signals.

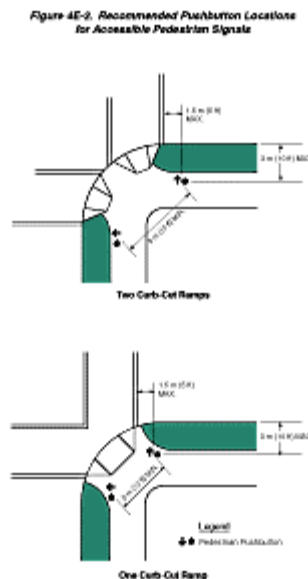
Guidance:

At accessible pedestrian signal locations, pushbuttons should clearly indicate which crosswalk signal is actuated by each pushbutton. Pushbuttons and tactile arrows should have high visual contrast as described in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see [Section 1A.11](#)). Tactile arrows should point in the same direction as the associated crosswalk. At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m (10 ft). This enables pedestrians who have visual disabilities to distinguish and locate the appropriate pushbutton.

Pushbuttons for accessible pedestrian signals should be located (see Figure 4E-2) as follows:

- A. Adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp;
- B. Within 1.5 m (5 ft) of the crosswalk extended;
- C. Within 3 m (10 ft) of the edge of the curb, shoulder, or pavement; and
- D. Parallel to the crosswalk to be used.

Figure 4E-2 Recommended Pushbutton Locations for Accessible Pedestrian Signals



If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector should be provided in the median.

Standard:

When used, pushbutton locator tones shall be easily located, shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.

Guidance:

Pushbuttons should be audibly locatable. Pushbutton locator tones should be intensity responsive to ambient sound, and

be audible 1.8 to 3.7 m (6 to 12 ft) from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dBA louder than ambient sound.

Pushbutton locator tones should be deactivated during flashing operation of the traffic control signal.

Option:

At locations with pretimed traffic control signals or nonactuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

The audible tone(s) may be made louder (up to a maximum of 89 dBA) by holding down the pushbutton for a minimum of 3 seconds. The louder audible tone(s) may also alternate back and forth across the crosswalk, thus providing optimal directional information.

The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print.

Section 4E.10 Pedestrian Intervals and Signal Phases

Standard:

When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.

A pedestrian clearance time shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. The first portion of the pedestrian clearance time shall consist of a pedestrian change interval during which a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed. The remaining portions shall consist of the yellow change interval and any red clearance interval (prior to a conflicting green being displayed), during which a flashing or steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed.

If countdown pedestrian signals are used, a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed during the yellow change interval and any red clearance interval (prior to a conflicting green being displayed) (see [Section 4E.07](#)).

At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal lenses shall not be illuminated.

Guidance:

Except as noted in the Option, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.

Option:

If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

Support:

The walk interval itself need not equal or exceed the pedestrian clearance time calculated for the roadway width, because many pedestrians will complete their crossing during the pedestrian clearance time.

Guidance:

The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 1.2 m (4 ft) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time.

Option:

Passive pedestrian detection equipment which can detect pedestrians who need more time to complete their crossing and can extend the length of the pedestrian clearance time for that particular cycle, may be used in order to avoid using a lower walking speed to determine the pedestrian clearance time.

Guidance:

Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian signals or additional signing.

Option:

The pedestrian clearance time may be entirely contained within the vehicular green interval, or may be entirely contained within the vehicular green and yellow change intervals.

On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided.

During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in [Section 4D.13](#).

The MUTCD's coverage of pedestrian signal control features is quite comprehensive, with guidance and recommendations on signal timing, pushbutton placement, colors and symbols, and accessible features. This report offers example guidelines, found in Chapter 3, that might be used to supplement the MUTCD recommendations. In contrast to the traffic signal warrants, multiway stop sign warrants in the MUTCD do not explicitly incorporate pedestrian volumes. An optional multiway stop sign warrant is expressed as "The need to control vehicle/pedestrian conflicts near locations that generate high pedestrian volumes." No specific guidance on the number or severity of conflicts, or a definition of "high pedestrian volume," is offered. Further, there is a general need for pedestrian safety interventions that extend beyond stop sign and traffic signal control.

Crosswalk markings are given the following discussion in the MUTCD:

Section 3B.17 Crosswalk Markings**Support:**

Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops.

Crosswalk markings also serve to alert road users of a pedestrian crossing point across roadways not controlled by highway traffic signals or STOP signs.

At nonintersection locations, crosswalk markings legally establish the crosswalk.

Standard:

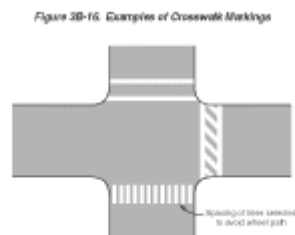
When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall be not less than 150 mm (6 in) nor greater than 600 mm (24 in) in width.

Guidance:

If transverse lines are used to mark a crosswalk, the gap between the lines should not be less than 1.8 m (6 ft). If diagonal or longitudinal lines are used without transverse lines to mark a crosswalk, the crosswalk should not be less than 1.8 m (6 ft) wide.

Crosswalk lines, if used on both sides of the crosswalk, should extend across the full width of pavement or to the edge of the intersecting crosswalk to discourage diagonal walking between crosswalks (see Figures 3B-15 and 3B-16).

[Figure 3B-16](#) Examples of Crosswalk Markings



Crosswalks should be marked at all intersections where there is substantial conflict between vehicular and pedestrian movements.

Marked crosswalks also should be provided at other appropriate points of pedestrian concentration, such as at loading islands, midblock pedestrian crossings, or where pedestrians could not otherwise recognize the proper place to cross.

Crosswalk lines should not be used indiscriminately. An engineering study should be performed before they are installed at locations away from highway traffic signals or STOP signs.

Because nonintersection pedestrian crossings are generally unexpected by the road user, warning signs (see [Section 2C.41](#)) should be installed and adequate visibility should be provided by parking prohibitions.

Support:

[Section 3B.16](#) contains information regarding placement of stop line markings near crosswalk markings.

Option:

For added visibility, the area of the crosswalk may be marked with white diagonal lines at a 45-degree angle to the line of the crosswalk or with white longitudinal lines parallel to traffic flow as shown in Figure 3B-16.

When diagonal or longitudinal lines are used to mark a crosswalk, the transverse crosswalk lines may be omitted. This type of marking may be used at locations where substantial numbers of pedestrians cross without any other traffic control device, at locations where physical conditions are such that added visibility of the crosswalk is desired, or at places where a pedestrian crosswalk might not be expected.

Guidance:

If used, the diagonal or longitudinal lines should be 300 to 600 mm (12 to 24 in) wide and spaced 300 to 1500 mm (12 to 60 in) apart. The marking design should avoid the wheel paths, and the spacing should not exceed 2.5 times the line width.

Option:

When an exclusive pedestrian phase that permits diagonal crossing is provided at a traffic control signal, a marking as shown in Figure 3B-17 may be used for the crosswalk.

[Figure 3B-17](#) Example of Crosswalk Markings for Exclusive Pedestrian Phase That Permits Diagonal Crossing



The MUTCD approves of the use of several crosswalk marking patterns other than the standard two transverse, solid white lines. The MUTCD is somewhat vague, though, on pedestrian crossing criteria at uncontrolled locations, in that no specific volumes, either for vehicles or pedestrians, are provided. Further, no guidance is provided on how the recommended “engineering study” should be conducted, what performance measures should be used, or what values of these measures might signify the need for pedestrian crossing improvements. There are also a number of crosswalk enhancements – some of which are still experimental – that deserve some attention. These are discussed in Chapter 2 of this report. Regarding stop and yield lines in advance of crosswalks, the MUTCD provides the following guidance:

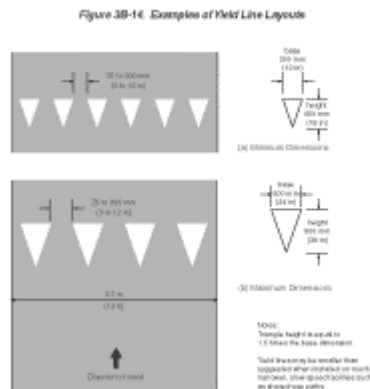
Section 3B.16 Stop and Yield Lines

Standard:

If used, stop lines shall consist of solid white lines extending across approach lanes to indicate the point at which the stop is intended or required to be made.

If used, yield lines (see Figure 3B-14) shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.

[Figure 3B-14](#) Examples of Yield Line Layouts



Guidance:

Stop lines should be 300 to 600 mm (12 to 24 in) wide.

Stop lines should be used to indicate the point behind which vehicles are required to stop, in compliance with a STOP (R1-1) sign, traffic control signal, or some other traffic control device, except YIELD signs.

The individual triangles comprising the yield line should have a base of 300 to 600 mm (12 to 24 in) wide and a height equal to 1.5 times the base. The space between the triangles should be 75 to 300 mm (3 to 12 in).

Option:

Yield lines may be used to indicate the point behind which vehicles are required to yield in compliance with a YIELD (R1-2) sign or a Yield Here to Pedestrians (R1-5 or R1-5a) sign.

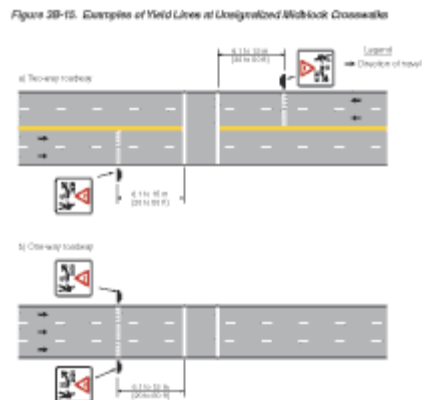
Guidance:

If used, stop and yield lines should be placed a minimum of 1.2 m (4 ft) in advance of the nearest crosswalk line at controlled intersections, except for yield lines at roundabout intersections as provided for in [Section 3B.24](#) and at midblock crosswalks. In the absence of a marked crosswalk, the stop line or yield line should be placed at the desired stopping or yielding point, but should be placed no more than 9 m (30 ft) nor less than 1.2 m (4 ft) from the nearest

edge of the intersecting traveled way. Stop lines should be placed to allow sufficient sight distance to all other approaches to an intersection.

If used at an unsignalized midblock crosswalk, yield lines should be placed adjacent to the Yield Here to Pedestrians sign located 6.1 to 15 m (20 to 50 ft) in advance of the nearest crosswalk line, and parking should be prohibited in the area between the yield line and the crosswalk (see Figure 3B-15).

Figure 3B-15 Examples of Yield Lines at Unsignalized Midblock Crosswalks



Stop lines at midblock signalized locations should be placed at least 12 m (40 ft) in advance of the nearest signal indication (see [Section 4D.15](#)).

Support:

Drivers who yield too close to crosswalks on multi-lane approaches place pedestrians at risk by blocking other drivers' views of pedestrians.

The MUTCD's recommendations are robust in that emphasis is placed on a combination of crosswalk markings, stop or yield lines, and signing. The discussion of sight distance and pedestrian visibility is also useful; perhaps even greater emphasis should be placed on the importance of the buffer between the stop or yield line and the pedestrian crossing. Additional advance warning strategies for drivers are examined in Chapter 4 of this report.

Pedestrian-oriented signing in the MUTCD consists of regulatory and warning signs directed at drivers, and regulatory signs directed at pedestrians. The following materials are excerpts, ordered as indicated in the preceding sentence:

Section 2B.11 Yield Here to Pedestrians (R1-5, R1-5a)

Standard:

If yield lines are used in advance of an unsignalized marked midblock crosswalk, Yield Here To Pedestrians (R1-5, R1-5a) signs (see Figure 2B-2) shall be placed 6.1 to 15 m (20 to 50 ft) in advance of the nearest crosswalk line (see [Section 3B.16](#) and [Figure 3B-15](#)).

Figure 2B-2 Unsignalized Pedestrian Crosswalk Signs

Figure 2B-3. Unsignalized Pedestrian Crosswalk Signs



Section 2B.12 In-Street Pedestrian Crossing Signs (R1-6, R1-6a)

Option:

The In-Street Pedestrian Crossing (R1-6 or R1-6a) sign (see Figure 2B-2) may be used to remind road users of laws regarding right of way at an unsignalized pedestrian crossing. The legend STATE LAW may be shown at the top of the sign if applicable. The legends STOP FOR or YIELD TO may be used in conjunction with the appropriate symbol.

Guidance:

If an island (See Chapter 3G) is available, the In-Street Pedestrian Crossing sign, if used, should be placed on the island.

Standard:

The In-Street Pedestrian Crossing sign shall not be used at signalized locations.

The STOP FOR legend shall only be used in States where the State law specifically requires that a driver must stop for a pedestrian in a crosswalk.

If used, the In-Street Pedestrian Crossing sign shall have a black legend (except for the red STOP or YIELD sign symbols) and border on either a white and/or fluorescent yellow-green background.

If the In-Street Pedestrian Crossing sign is placed in the roadway, the sign support shall comply with the breakaway requirements of the latest edition of AASHTO's "Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" (See [Addresses](#)).

Support:

The provisions of [Section 2A.18](#) concerning mounting height are not applicable for the In-Street Pedestrian Crossing sign.

Option:

The In-Street Pedestrian Crossing sign may be used seasonably to prevent damage in winter because of plowing operations, and may be removed at night if the pedestrian activity at night is minimal.

Section 2C.41 Nonvehicular Signs (W11-2, W11-3, W11-4, W11-6, W11-7, W11-9)

Option:

Nonvehicular signs (see Figure 2C-10) may be used to alert road users in advance of locations where unexpected entries into the roadway or shared use of the roadway by pedestrians, animals, and other crossing activities might occur.

[Figure 2C-10](#) Nonvehicular Traffic Signs

Figure 2C-10. Nonvehicular Traffic Signs

**Support:**

These conflicts might be relatively confined, or might occur randomly over a segment of roadway.

Option:

When used in advance of a crossing, Nonvehicular warning signs may be supplemented with supplemental plaques (see [Section 2C.43](#)) with the legend AHEAD, XX METERS (XX FEET), or NEXT XX km (NEXT XX MILES) to provide advance notice to road users of crossing activity.

Standard:

When used at the crossing, Nonvehicular signs shall be supplemented with a diagonal downward pointing arrow (W16-7p) plaque (see Figure 2C-11) showing the location of the crossing.

Figure 2C-11 Supplemental Warning Plaques

**Option:**

The crossing location may be defined with crosswalk markings (see [Section 3B.17](#)).

Pedestrian, Bicycle, and School signs and their related supplemental plaques may have a fluorescent yellow-green background with a black legend and border.

Guidance:

When a fluorescent yellow-green background is used, a systematic approach featuring one background color within a zone or area should be used. The mixing of standard yellow and fluorescent yellow-green backgrounds within a selected site area should be avoided.

Nonvehicular signs should be used only at locations where the crossing activity is unexpected or at locations not readily apparent.

Section 2B.43 WALK ON LEFT FACING TRAFFIC and No Hitchhiking Signs (R9-1, R9-4, R9-4a)

Option:

The WALK ON LEFT FACING TRAFFIC (R9-1) sign (see Figure 2B-18) may be used on highways where no sidewalks are provided.

Standard:

If used, the WALK ON LEFT FACING TRAFFIC sign shall be installed on the right side of the road where pedestrians walk on the pavement or shoulder in the absence of pedestrian pathways or sidewalks.

Option:

The No Hitchhiking (R9-4a) sign (see Figure 2B-18) may be used to prohibit standing in or adjacent to the roadway for the purpose of soliciting a ride. The R9-4 word message sign (see Figure 2B-18) may be used as an alternate to the R9-4a symbol sign.

[Figure 2B-18](#) Pedestrian Signs



Section 2B.44 Pedestrian Crossing Signs (R9-2, R9-3)

Option:

Pedestrian Crossing signs (see Figure 2B-18) may be used to limit pedestrian crossing to specific locations.

Standard:

If used, Pedestrian Crossing signs shall be installed to face pedestrian approaches.

Option:

Where crosswalks are clearly defined, the CROSS ONLY AT CROSSWALKS (R9-2) sign may be used to discourage jaywalking or unauthorized crossing.

The No Pedestrian Crossing (R9-3a) sign may be used to prohibit pedestrians from crossing a roadway at an undesirable location or in front of a school or other public building where a crossing is not designated.

The NO PEDESTRIAN CROSSING (R9-3) word message sign may be used as an alternate to the R9-3a symbol sign. The USE CROSSWALK (R9-3b) supplemental plaque, along with an arrow, may be installed below either sign to designate the direction of the crossing.

Support:

One of the most frequent uses of the Pedestrian Crossing signs is at signalized intersections that have three crossings that can be used and one leg that cannot be crossed.

Guidance:

The R9-3b sign should not be installed in combination with educational plaques.

Section 2B.45 Traffic Signal Signs (R10-1 through R10-21)

Option:

To supplement traffic signal control, Traffic Signal signs R10-1 through R10-21 may be used to regulate road users.

Guidance:

When used, Traffic Signal signs should be located adjacent to the signal face to which they apply.

Standard:

Traffic Signal signs applicable to pedestrian actuation (see [Figure 2B-18](#)) shall be mounted immediately above or incorporated in pedestrian pushbutton units (see [Section 4E.08](#)).

Support:

Traffic Signal signs applicable to pedestrians include:

- A. CROSS ON GREEN LIGHT ONLY (R10-1);
- B. CROSS ON WALK SIGNAL ONLY (R10-2);
- C. PUSH BUTTON FOR GREEN LIGHT (R10-3); and
- D. PUSH BUTTON FOR WALK SIGNAL (R10-4).

Option:

The following signs may be used as an alternate for the R10-3 and R10-4 signs:

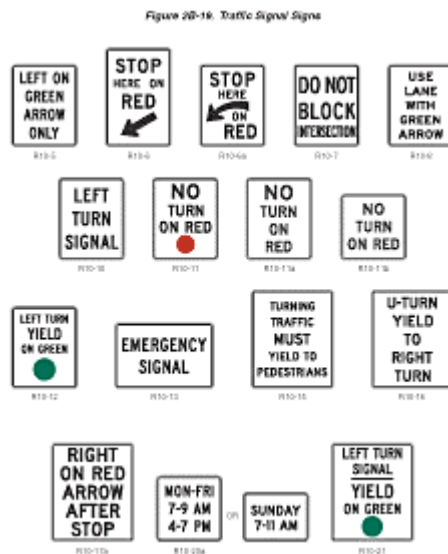
- A. TO CROSS STREET (arrow), PUSH BUTTON WAIT FOR GREEN LIGHT (R10-3a); and
- B. TO CROSS STREET (arrow), PUSH BUTTON WAIT FOR WALK SIGNAL (R10-4a).

The symbol sign R10-2a may be used as an alternate to sign R10-2. Where symbol-type pedestrian signal indications are used, an educational sign (R10-3b) may be used to improve pedestrian understanding of pedestrian indications at signalized intersections. Where word-type pedestrian signal indications are being retained for the remainder of their useful service life, the legends WALK/DONT WALK may be substituted for the symbols on the educational sign R10-3b, thus creating sign R10-3c. The R10-3d sign may be used if the pedestrian clearance time is sufficient only for the pedestrian to cross to the median. The diagrammatic sign R10-4b may also be used as an alternate to sign R10-4. At intersections where pedestrians cross in two stages using a median refuge island, the word message "CROSS TO MEDIAN" may be placed on the near corner of the refuge island along with the educational plaque.

Regarding regulatory signage for drivers, the MUTCD offers an option for turning drivers, as follows:

In order to remind drivers who are making turns to yield to pedestrians, especially at intersections where right turn on red is permitted and pedestrian crosswalks are marked, a TURNING TRAFFIC MUST YIELD TO PEDESTRIANS (R10-15) sign may be used (see Figure 2B-19).

[Figure 2B-19](#) Traffic Signal Signs



A number of alternative signs directed at drivers and pedestrians have been studied; several of these are examined in this report (primarily in Chapters 2, 5 and 6). There is limited information available on the effectiveness of any of the signs, thereby leaving many situations to engineering judgment. Also, there are no standard warning signs directed at pedestrians; such signing might contribute to improving pedestrian safety.

The MUTCD offers a separate chapter on traffic controls in school areas. The primary consideration in the discussion is the safety of pedestrians and cyclists within school zones and along school access routes. Since this report's emphasis is on pedestrian safety *in general*, the MUTCD's school areas chapter is not repeated here. The research team considered school zones and routing to be a special concern worthy of a separate examination. As of the preparation of this report, UDOT was funding a research study on school zone and school access routing safety; the results of the study were not available at press time. A discussion of school zones and child pedestrians is offered in Chapter 7 of this report, though, as a means of establishing a connection between broad pedestrian safety concerns, and those involving children.

1.3 Current Utah Pedestrian-Related Laws and Ordinances

Municipality Example: St. George. Numerous local jurisdictions throughout Utah have supplemented UDOT policy with their own guidelines regarding pedestrian crossings. Many of these guidelines are part of a municipal code. A common thread among many local agencies is the results of a study conducted in San Diego, California in the early 1970s (Herms 1972). The City of St. George (www.ci.st-george.ut.us/publicworks/brochures/markedxwalks.php), for example, states:

Crosswalks are marked mainly to encourage pedestrians to use a particular crossing. Studies conducted on the relative safety of crosswalks support minimal installation of marked crosswalks. The City of San Diego, California, studied intersections at which there were both marked and unmarked crosswalks. The results were surprising. Although 2 ½ times as many people used the marked crosswalks, 6 times as many accidents occurred in the marked crosswalks. A pedestrian safety study in Long Beach, California, reported 8 times as many accidents in marked cross walks compared to unmarked crosswalks. Similar studies in other cities have confirmed these results.

Research suggests that marked crosswalks give pedestrians a false sense of security. Pedestrians often step off the curb into the crosswalk expecting drivers of approaching vehicles to stop. However, drivers frequently fail to stop and cause an accident. At all crosswalks, both marked and unmarked, it is the pedestrian's responsibility to be cautious and alert when crossing the street. At mid-block crosswalks on multi-lane roadways, another frequent factor in causing accidents involves the driver of a vehicle in the lane nearest to the curb stopping for a pedestrian that is

waiting to cross or who is already in the crosswalk. The driver of a second vehicle traveling in the lane next to the stopped vehicle tried to pass the stopped vehicles and hits the pedestrian, even though it is illegal for drivers to pass a stopped vehicle at a crosswalk. Pedestrians should be very cautious when walking in a crosswalk, especially when their visibility is limited by vehicles already stopped at the crosswalk.

Crosswalks are marked at intersections where there is substantial conflict between vehicle and pedestrian movements, where significant pedestrian concentrations occur, where pedestrians could not otherwise recognize the proper place to cross, and where traffic movements are controlled. Examples of such locations are approved school crossings, and signalized and four-way stop intersections where there is significant pedestrian traffic and one or more crossing locations have been prohibited. These examples follow the philosophy of marking crosswalks as a form of encouragement. In the first case, we are encouraging school children to use a crossing which is normally being monitored. In the second case, we are encouraging all pedestrians to avoid a prohibited crossing. It is the City's policy not to paint crosswalks at midblock locations where traffic is not controlled by stop signs or traffic signals. Painted crosswalks should only be used where necessary to direct pedestrians along the safest route.

Although St. George's pedestrian crossings policies are not necessarily representative of all Utah jurisdictions, they are an example, perhaps, of what is typical. The Salt Lake City Department of Transportation has been exceptionally aggressive and innovative in its approach to pedestrian safety, however. Salt Lake City's actions are referenced throughout this report. School zone crossings in St. George, and in other cities, throughout Utah, are treated differently and separately from other pedestrian crossings. Further discussion of school zones and child pedestrians is provided in a section 7.3.

Utah Administrative Code: Definitions and Motor Vehicles (Title 41). (*The following section features excerpts from the Utah Administrative Code, current as of April 2004*). Title 31A, Chapter 22, Section 301 (31-22A-301), Part 7 of the Utah Code offers the following definition: "Pedestrian means any natural person not occupying a motor vehicle." Section 41-6-1, Part 32 offers "Pedestrian means any person afoot." Section [41-6-1](#), Part 7 identifies a pedestrian crossing as follows: "Crosswalk means:

- (a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway; and in the absence of a sidewalk on one side of the roadway, that part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline; or
- (b) any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface."

Other definitions offered in Section [41-6-1](#) of the Code are as follows. In Part 42, "Safety zone means the area or space officially set apart within a roadway for the exclusive use of pedestrians and which is protected, marked, or indicated by adequate signs as to be plainly visible at all times while set apart as a safety zone." In Part 46, "Sidewalk means that portion of a street between the curb lines, or the lateral lines of a roadway, and the adjacent property lines intended for the use of pedestrians."

Legislation related to traffic signals as described in Section [41-6-24](#) includes the following. From Part 1(a): "Green, red, and yellow are the only colors that may be used in traffic-control signals, except for special pedestrian signals that may use white and orange." From Part 2(a)(ii), "Vehicular traffic facing a circular green signal, including vehicles turning right or left shall yield the right-of-way to other vehicles and to pedestrians lawfully within the intersection or an adjacent crosswalk at the time the signal is exhibited." From Part 2(b)(ii), "Vehicular traffic facing a green arrow signal shown alone or in combination with other indication: shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection unless otherwise directed by a pedestrian-control signal under Section [41-6-25](#), pedestrians facing any green signal other than a green turn arrow may proceed across the roadway within any marked or unmarked crosswalk." From Part 3(b), "Unless otherwise directed by a pedestrian-control signal under Section [41-6-25](#), pedestrians facing a steady circular yellow or yellow arrow signal are advised that there is insufficient time to cross the roadway before a red indication is shown, and a pedestrian may not start to cross the roadway." From Part 4(a)(ii), "Vehicular traffic facing a steady circular red or red arrow signal shall stop at a clearly marked stop line,

but if none, before entering the marked or unmarked crosswalk on the near side of the intersection and shall remain stopped until an indication to proceed is shown.” From Part 4(b), “Unless otherwise directed by a pedestrian-control signal under Section [41-6-25](#), pedestrians facing a steady red signal alone may not enter the roadway. From Part 4(c)(ii), “The vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.”

Section [41-6-25](#) refers to pedestrian signals, as follows: “When special pedestrian-control signals exhibiting the words ‘Walk’ or ‘Don’t Walk’ or symbols of ‘Walking Person’ or ‘Upraised Palm’ are in place, the signals indicate:

- (a) Flashing or steady ‘Walk’ or symbol of ‘Walking Person’ means a pedestrian facing the signal may proceed across the roadway in the direction of the signal and the operators of all vehicles shall yield the right-of-way to him.
- (b) Flashing or steady ‘Don’t Walk’ or ‘Upraised Palm’ means a pedestrian may not start to cross the roadway in the direction of the signal, but a pedestrian who has partially completed his crossing on the walk signal shall proceed to a sidewalk or safety island while the ‘Don’t Walk’ or ‘Upraised Palm’ signal is showing.”

Further legislation related to traffic controls is found in Section [41-6-77](#), as follows: “(1) A pedestrian shall obey the instructions of any official traffic-control device specifically applicable to him unless otherwise directed by a peace officer. (2) Pedestrians are subject to traffic and pedestrian-control signals under Sections [41-6-24](#) and [41-6-25](#).”

A large portion of Section [41-6-24](#) pertains to motorists yielding to pedestrians, as described above. Further regulations are found in Section [41-6-80](#), as follows: “The operator of a vehicle shall exercise care to avoid colliding with any pedestrian and shall give an audible signal when necessary and exercise appropriate precaution upon observing any child or any obviously confused, incapacitated, or intoxicated person. This section supersedes any conflicting provision of this chapter or of a local ordinance.” When a motorist must cross a sidewalk, Section [41-6-80.5](#) states: “The operator of a vehicle crossing a sidewalk shall yield the right-of-way to any pedestrian and all other traffic on the sidewalk.” Also, when a motorist emerges from a parking area or alley, Section [41-6-100](#) states: “The driver of a vehicle emerging from an alley, building, private road or driveway within a business or residence district shall stop such vehicle immediately prior to driving onto a sidewalk or onto the sidewalk area extending across such alley, building entrance, road or driveway, or in the event there is no sidewalk area, shall stop at the point nearest the street to be entered where the driver has a view of approaching traffic thereon.”

Section [41-6-72.10](#) concerns right-of-way at and collisions in intersections. Part 3(b) states: “After slowing or stopping, the operator shall yield the right-of-way to any vehicle in the intersection or approaching on another roadway so closely as to constitute an immediate hazard during the time the operator is moving across or within the intersection or junction of roadways. The operator shall yield to pedestrians within an adjacent crosswalk. If the operator is involved in a collision with a vehicle in the intersection or junction of roadways or with a pedestrian at an adjacent crosswalk, after passing a yield sign without stopping, the collision is prima facie evidence of the operator's failure to yield the right-of-way, but is not considered negligence per se in determining liability for the accident.”

Regulations relating to motor vehicle encroachment into the space of a crosswalk are given in Section [41-6-109.10](#): “No driver shall enter an intersection or a marked crosswalk or drive onto any railroad grade crossing unless there is sufficient space on the other side of the intersection, crosswalk, or railroad grade crossing to accommodate the vehicle he is operating without obstructing the passage of other vehicles, pedestrians, or railroad trains notwithstanding any traffic-control signal indication to proceed.”

Further laws relating to pedestrian right-of-way are expressed in Section [41-6-78](#): “(1) (a) Except as provided under Subsection (2), when traffic-control signals are not in place or not in operation, the operator of a vehicle shall yield the right-of-way, slowing down or stopping if necessary to yield, to a pedestrian crossing the roadway within a crosswalk when the pedestrian is upon the half of the roadway

upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger. This subsection does not apply under conditions of Subsection [41-6-79](#) (2). (b) A pedestrian may not suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard. (2) The operator of a vehicle approaching a school crosswalk shall come to a complete stop at the school crosswalk if: (a) a school speed limit sign has the warning lights operating; and (b) the crosswalk is occupied by any person. (3) If a vehicle is stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway, the operator of any other vehicle approaching from the rear may not overtake and pass the stopped vehicle.”

Further regulations regarding pedestrians *yielding* right-of-way are found in Section [41-6-79](#), as follows:

“(1) A pedestrian crossing a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right-of-way to all vehicles on the roadway.

(2) A pedestrian crossing a roadway at a point where there is a pedestrian tunnel or overhead pedestrian crossing shall yield the right-of-way to all vehicles upon the roadway.

(3) Between adjacent intersections at which traffic-control signals are in operation, pedestrians may not cross at any place except in a marked crosswalk.

(4) A pedestrian may not cross a roadway intersection diagonally unless authorized by official traffic-control devices, and if authorized to cross diagonally, shall cross only as directed by the appropriate official traffic-control devices.”

Legislation allows the designation of unmarked crossings, as explained in Section [41-6-82.10](#): “The Department of Transportation and local authorities in their respective jurisdictions may after an engineering and traffic investigation designate unmarked crosswalk locations where pedestrian crossing is prohibited or where pedestrians shall yield the right-of-way to vehicles. The restrictions are effective only when official traffic-control devices indicating the restrictions are in place.”

Pedestrians must yield the right-of-way to emergency vehicles, as described in Section [41-6-79.10](#): “(1) Upon the immediate approach of an authorized emergency vehicle using audible or visual signals meeting the requirements of Section [41-6-14](#), [41-6-132](#), or [41-6-146](#), or of a peace officer vehicle properly and lawfully making use of an audible or visual signal, every pedestrian shall yield the right-of-way to the authorized emergency vehicle.”

Pedestrian walkway provisions of the Utah Code are in Section [41-6-82](#), as follows: “(1) Where there is a sidewalk provided and its use is practicable, a pedestrian may not walk along and upon an adjacent roadway. “(2) Where a sidewalk is not provided, a pedestrian walking along and upon a highway shall walk only on a shoulder, as far as practicable from the edge of the roadway. (3) Where neither a sidewalk or a shoulder is available, a pedestrian walking along or upon a highway shall walk as near as practicable to an outside edge of the roadway, and if on a two-way roadway, shall walk only on the left side of the roadway. (4) A person may not sit, stand, or loiter in or near a roadway for the purpose of soliciting from the occupant of any vehicle a ride, contributions, employment, the parking, watching, or guarding of a vehicle, or other business. (5) A pedestrian who is under the influence of alcohol or any drug to a degree which renders him a hazard may not walk or be upon a highway except on a sidewalk or sidewalk area. (6) Except as otherwise provided in this chapter, a pedestrian upon a roadway shall yield the right-of-way to all vehicles upon the roadway.”

In reference to highway workers, Section [41-6-76.10](#) states: “The operator of a vehicle shall yield the right-of-way to any: (1) authorized vehicle or pedestrian actually engaged in work upon a highway within any highway construction or maintenance area indicated by official traffic-control devices.” In reference to railroad crossings, Section [41-6-79.20](#) states: “A pedestrian may not pass through, around, over, under, or remain upon any crossing gate or barrier at a railroad crossing or bridge while the gate or

barrier is closed or is being opened or closed.” Section [41-6-80.1](#) describes legislation relating to visually-impaired pedestrians, as follows:

- “(1) (a) The operator of a vehicle shall yield the right-of-way to any blind or visually impaired pedestrian carrying a clearly visible white cane or accompanied by a guide dog specially trained for that purpose and equipped with a harness.
(b) A person who fails to yield the right-of-way is liable for any loss or damage which results as a proximate cause of failure to yield the right-of-way to blind or visually impaired persons, except that blind or visually impaired persons shall exercise due care in approaching and crossing roadways and shall yield right-of-way to emergency vehicles giving an audible warning signal.
(2) A pedestrian other than a blind or visually impaired person may not carry a cane as described in Subsection (1).”

Utah Administrative Code: Pedestrian Safety and Facilities Act (Title 72, Chapter 8). This Act legislated actions related to pedestrian planning and construction, including the following from Section [72-8-104](#):

- “(1) A county or municipality may use a portion of their B and C road funds for pedestrian safety devices under this part.
(2) The county legislative body of the counties and the governing officials of participating municipalities may establish funding priorities relating to construction of curbs, gutters, sidewalks, or other pedestrian safety construction, with funds permitted to be expended by this part, based on factors including, but not limited to:
(a) existing useable rights-of-way;
(b) vehicle-pedestrian accident experience;
(c) average daily vehicle traffic;
(d) average daily pedestrian traffic;
(e) average daily school age pedestrian traffic; and
(f) speed of vehicle traffic.
(3) All construction performed under this part shall be barrier free to wheelchairs at crosswalks and intersections.”

Section [72-8-105](#) states: “A highway authority shall consider pedestrian safety in all highway engineering and planning where pedestrian traffic may be a significant factor on all projects within the state or any of its political subdivisions.”

Utah Administrative Code: School Zones and Crossings. School zones and crossings are addressed in Title 41, Chapter 6. Section [41-6-20.1](#) states:

- “(1) As used in this section ‘reduced speed school zone’ means a designated length of a highway extending from a school speed limit sign while the warning lights are operating to an end school zone sign.
(2) The Department of Transportation for state highways and local authorities for highways under their jurisdiction:
(a) shall establish reduced speed school zones at elementary schools after written assurance by a local authority that the local authority complies with Subsections (3) and (4); and
(b) may establish reduced speed school zones for secondary schools at the request of the local authority.
(3) For all reduced speed school zones on highways, including state highways within the jurisdictional boundaries of a local authority, the local authority shall:
(a) (i) provide shuttle service across highways for school children; or
(ii) provide, train, and supervise school crossing guards in accordance with this section;

- (b) provide for the:
 - (i) operation of reduced speed school zones, including providing power to warning lights and turning on and off the warning lights as required under Subsections (4) and (5); and
 - (ii) maintenance of reduced speed school zones except on state highways as provided in Section [41-6-21](#); and
- (c) notify the Department of Transportation of reduced speed school zones on state highways that are in need of maintenance.
- (4) While children are going to or leaving school during opening and closing hours all reduced speed school zones shall have:
 - (a) the warning lights operating on each school speed limit sign; and
 - (b) a school crossing guard present if the reduced speed school zone is for an elementary school.
- (5) The warning lights on a school speed limit sign may not be operating except as provided under Subsection (4).
- (6) In accordance with Title 63, Chapter 46a, Utah Administrative Rulemaking Act, the Department of Transportation shall make rules establishing criteria and specifications for the:
 - (a) establishment, location, and operation of school crosswalks, school zones, and reduced speed school zones;
 - (b) training, use, and supervision of school crossing guards at elementary schools and secondary schools; and
 - (c) content and implementation of child access routing plans under Section [53A-3-402](#).
- (7) Each local authority shall pay for providing, training, and supervising school crossing guards in accordance with this section.”

Section [41-6-46](#) legislates the following regarding motor vehicle speeds in school zones: “(2) If no special hazard exists, and subject to Subsection (4) and Sections [41-6-47](#) and [41-6-48](#), the following speeds are lawful: (a) 20 miles per hour in a reduced speed school zone as defined in Section [41-6-20.1](#).” Section [41-6-48.5](#) describes the penalties and fines associated with violating school zone speed limits.

Section [53A-3-402](#) discusses school traffic safety committee formation and access routing planning, as follows:

- “(17)(a) Each board shall establish for each school year a school traffic safety committee to implement this Subsection (17).
- (b) The committee shall be composed of one representative of:
 - (i) the schools within the district;
 - (ii) the Parent Teachers' Association of the schools within the district;
 - (iii) the municipality or county;
 - (iv) state or local law enforcement; and
 - (v) state or local traffic safety engineering.
 - (c) The committee shall:
 - (i) receive suggestions from parents, teachers, and others and recommend school traffic safety improvements, boundary changes to enhance safety, and school traffic safety program measures;
 - (ii) review and submit annually to the Department of Transportation and affected municipalities and counties a child access routing plan for each elementary, middle, and junior high school within the district;
 - (iii) consult the Utah Safety Council and the Division of Family Health Services and provide training to all school children in kindergarten through grade six, within the district, on school crossing safety and use; and
 - (iv) help ensure the district's compliance with rules made by the Department of Transportation under Section [41-6-20.1](#).

- (d) The committee may establish subcommittees as needed to assist in accomplishing its duties under Subsection (17)(c).
- (e) The board shall require the school community council of each elementary, middle, and junior high school within the district to develop and submit annually to the committee a child access routing plan.”

The Utah Code’s legislation on school zones was established in 1992 under the School Zone Safety Act. *Manual and Specifications on School Crossing Zones* was subsequently prepared by UDOT to provide guidance for school access route design, the usage of crossing guards, and traffic control practices.

Discussion. This study did not attempt to draw a solid connection between state and municipal ordinances and any example pedestrian crossing guidelines. Reference is made to current policies and rules as needed to properly address certain pedestrian safety issues. Current Utah Code contains extensive legislation related to pedestrian actions and duties, and motorist obligations when crossing pedestrian paths. The Code lacks specific criteria on the establishment of pedestrian safety interventions, though, and must be supplemented by local and state policies and guidelines. The implementation of any of the example guidelines presented in this study might involve data collection, experimentation, further literature reviews, effectiveness evaluations, benefit-cost analysis, and site-specific investigations. This report should serve as a resource for pedestrian safety improvement strategizing.

1.4 Background on Research Done for this Study

This study contains a set of example guidelines that address pedestrian crossing safety issues in Utah. Most of the example guidance addresses, either directly or indirectly, current local and state policy regarding pedestrian crossings. To facilitate the development of the example guidelines, a sample of 294 sites was developed from the 6,610 sites at which a pedestrian-vehicle collision occurred within the state of Utah between 1992 and 2001. Further discussion of how the 294 sites were identified and selected is provided in the Technical Document, which is a companion to this report. A total of 990 of Utah’s 8,838 pedestrian-vehicle crashes, all occurring during the ten-year study period, were “represented” by the sites included in the sample. A map showing the distribution by county of pedestrian-vehicle crashes occurring in the state between 1992 and 2001 is presented in Figure 1. The general locations of the sampled crash sites are shown in Figure 2. The University of Utah research team visited about 200 of the sites during 2003 and 2004 to collect pedestrian and motor vehicle infrastructure information. By examining the facilities at each site, it was possible to identify potential shortcomings in the pedestrian and motorist provisions – these shortcomings may have been causal factors in the incidents.

The field data were supplemented by information recorded on year 2000 and 2001 Police Accident Reports (PARs) on fatal pedestrian-vehicle collisions that occurred at the sampled sites. A total of 335 pedestrian fatalities occurred in Utah between 1992 and 2001, with 58 occurring during 2000 and 2001. A total of 52 of these occurred at the 294 sites in the crash sample.

In examining the data from the 200 pedestrian-vehicle crash sites visited, along with 34 PARs (some of the PARs were associated with crash sites visited), a number of recurring issues were identified. The issues were separated into two groups: issues that might be serviced by infrastructure, planning or policy, and issues that might be resolved by education and vigilance. The research team elected to focus on the infrastructure-, planning-, and policy-related issues, rather than the other issues. The supposition was that pedestrian crossing guidelines would be most directly connected with infrastructure, planning and policy. Education and vigilance would bear an indirect relationship to the state guidelines, thereby warranting separate consideration. Education and vigilance might generate improvements in pedestrian visibility (i.e., brightness of clothing), pedestrian crossing judgment, driver attentiveness, errant driving, driving or walking under the influence, and driver yielding behavior, among others.

A total of 21 infrastructure, planning and policy issues were identified. The issues are listed and grouped below. Each issue is discussed individually within the chapter pertaining to that issue's group. Within each section of each chapter, each issue is defined in greater detail; then, a brief review of the findings in the literature is presented, followed by a summary of what Portland, Florida, New Jersey and Washington are doing about the issue, a brief discussion, including reference as needed to current activities in Utah, and a set of example guidelines that might be considered in Utah.

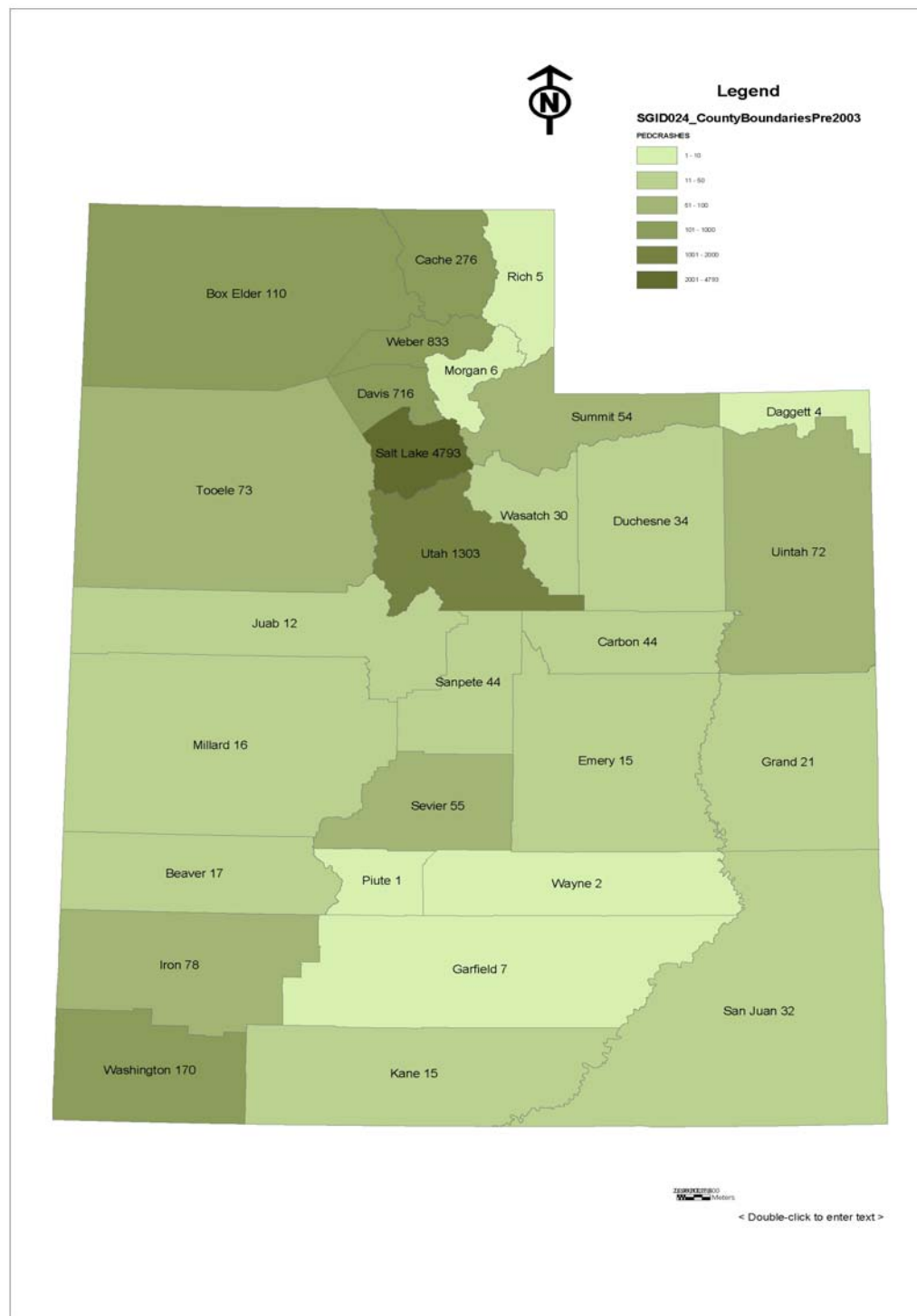


Figure 1. Map: Distribution of Pedestrian-Vehicle Crashes in Utah by County, 1992-2001



Figure 2. General Locations of Sampled Pedestrian-Vehicle Crash Sites

1.5 List of 21 Recurring Infrastructure, Planning and Policy Issues

The 21 issues are listed below. Each issue is explored in some detail in the associated chapter, as noted.

Pedestrian Crossing Facilities and Enhancements (*Chapter 2*)

- Pedestrian crossings at bus stops
- Locating marked crossings
- Pedestrian refuges
- Pedestrian crossing enhancements
- Guidance for pedestrians at crossings
- Pedestrian crossing flags

Pedestrian Signals (*Chapter 3*)

- Pedestrian green time
- All-red clearance intervals during pedestrian signal cycles
- Pedestrian signal maintenance
- Pedestrian signal enhancements
- Pedestrian signal responsiveness

Pedestrian Facility Construction (*Chapter 4*)

- Sidewalk construction and installation policy
- Grade-separated pedestrian crossings

Pedestrian-Turning Vehicle Conflicts (*Chapter 5*)

- Conflicts between pedestrians and right-turning vehicles
- Conflicts between pedestrians and left-turning vehicles

Measures and Strategies Targeted at Drivers (*Chapter 6*)

- Placement of warnings to drivers
- Effectiveness of signing only at a crossing
- Motorist stopping behavior, policy and law
- Driver penalties following pedestrian-vehicle collisions

Other Issues (*Chapter 7*)

- Pedestrian volume data collection and usage
- Pedestrian visibility enhancement
- School zones and child pedestrians

CHAPTER 2.0 Pedestrian Crossing Facilities and Enhancements

2.1 Pedestrian Crossings at Bus Stops

Problem Statement. There are numerous locations throughout the Utah Transit Authority service area – and, possibly, in other Utah transit system service areas – at which there is no marked crossing adjacent a bus stop. The pedestrian who is either accessing or leaving the stop may need to cross a street or highway at an unmarked location. A number of pedestrian-vehicle collisions have occurred in the vicinity of bus stops at which there is no marked crossing nearby.

Literature Review. The Institute of Transportation Engineers recommends that a midblock crossing be provided at transit stops that are located across from land uses that generate high concentrations of pedestrians who need to cross, such as residential areas and places of employment. A midblock crossing is *not* recommended, though, at a bus stop where motorists are “not expecting” pedestrians to cross.

The Tri-County Metropolitan Transportation District of Oregon (TriMet), which serves the Portland, Oregon area, has developed criteria for pedestrian crossing improvement needs adjacent bus stops (Khan 2002). The criteria consider the posted speed limit, the proximity of the stop to a traffic signal, sight distance, the number of travel lanes, the roadway width, the average daily traffic volume (ADT), the number of pedestrian-vehicle collisions within 200 ft of the bus stop within the past three years, the traffic environment (number of driveways, amount of lane-changing activity), and the existence and condition of the sidewalk. A scoring system produces a low value for bus stops at which crossing improvements are needed. The criteria, somewhat surprisingly, do not consider the amount of passenger activity at a bus stop. A research project entitled *Improving Pedestrian Safety at Unsignalized Roadway Crossings*, jointly funded by the Transit and National Highway Cooperative Research Programs, is being conducted by Texas A&M University. The work is scheduled for completion in November 2004. One of the project’s emphases is on pedestrian crossing needs at uncontrolled locations adjacent transit stops.

Portland, Oregon. No specific guidance is provided.

Florida. No specific guidance is provided.

New Jersey. A crosswalk should be located within 400 m of a transit station. A crosswalk combined with illumination should be considered at bus stops, rail stations, and other mass transit transfer locations.

Washington. The cities of Bellevue and Kirkland both mention the need for marked crossings at transit stops; Kirkland refers to the “significant benefit to transit” that might be provided by a marked crossing. The State recommends that pedestrian-actuated signals be used at heavily-used midblock bus stops.

Discussion. Only limited guidance is provided in the literature on pedestrian crossings and bus stops. The 400 m distance recommended in New Jersey’s guidelines is quite long, and may in fact be somewhat ineffective. The findings of the TCRP-NCHRP research should be investigated once they are published, as the guidance will be based on a national-level examination. Until the final report from this study is available, the TriMet criteria for pedestrian crossings adjacent bus stops should be considered.

Example Guidelines. *The Utah Department of Transportation and the Utah Transit Authority should collaborate, possibly with the Wasatch Front Regional Council and the Mountainland Association of Governments, to develop a policy for pedestrian crossings at bus stops. Other players might include Park City Transit, other transit agencies operating within Utah, and the cities within the service areas of these agencies. The crossing criteria should consider those that have been explored by TriMet, as well as the findings, due to be released in November 2004, of the TCRP-NCHRP research on transit stops at uncontrolled locations. The TriMet criteria are shown in Table 1. A low score is associated with a*

Table 1. Example Criteria for Rating Pedestrian Access at a Bus Stop (Khan 2002)

	Factor	Score	Conditions
1	Posted speed limit	15 12 9 6 3	25 MPH 30 MPH 35 MPH 40 MPH 45 MPH and above
2	Distance to nearest signal	20 16 12 8 4 0	< 20 ft 20-100 ft > 100 ft with marked crosswalk & refuge > 100 ft with marked crosswalk & no refuge > 100 ft with refuge & no marked crosswalk > 100 ft with no crosswalk or refuge
3	Sight distance ^a	10 8 6 4 2	> 10 * (posted speed in MPH) > 8-9 * (posted speed) > 6-7 * (posted speed) > 4-5 * (posted speed) < 4 * (posted speed)
4	Number of travel lanes	10 9 8 7 6 5 4 3 2	2 (2 one-way lanes) 2 (two way; 1 lane in each direction) 3 (3 one-way lanes) 3 (two way; 2 lanes in one direction) 4 (4 one-way lanes) 4 (two way; 2 lanes in each direction) 5 (5 one-way lanes) 5 (two way; 3 lanes in one direction) 6 (two way; 3 lanes in each direction)
5	Pavement width	5 4 3 2 1 0	< 50 ft 50-59 ft 60-69 ft 70-79 ft 80-89 ft 90-110 ft
6	ADT (average daily traffic volume)	10 8 6 4 2	< 10,000 10,000-20,000 20,000-30,000 30,000-40,000 > 40,000
7	Pedestrian-vehicle crashes within 200 ft of bus stop	5 4 3 2 1	0 in past 3 years 1 in past 3 years 2 in past 3 years 3 in past 3 years 4 or more in past 3 years
8	Traffic environment within 200 ft of bus stop	20 16 12 8 4 0	No driveways, no weaving, few lane changes 1-2 driveways 3-4 driveways, some weaving 5-6 driveways ? (not specified in Khan 2002; 7-8 driveways?) High weaving, high number of turns
9	Sidewalks	5 4 3 2 1 0	Smooth surface, 5 ft wide, with curb ramps Uneven surface, < 5 ft wide, with curb ramps Smooth surface, 5 ft wide, no curb ramps Uneven surface, < 5 ft wide, no curb ramps Substandard condition; only one side of road No sidewalks

^a Based on 11 ft of sight distance per MPH of speed.

greater need for pedestrian crossing facilities. Note that the criteria determine the need for a pedestrian crossing facility at or adjacent a bus stop. The criteria are not necessarily integrated with the placement of bus stops. If the number of travel lanes exceeds six, then use a score of 1 or 0. It is not known if the criteria have been verified through application in Portland, but they may be acceptable as an interim set of guidelines until the TCRP-NCHRP research is done. The scores might be used to prioritize and rank bus stop locations in terms of their need for pedestrian crossing facilities. Further work would be needed to develop a policy for pedestrian crossing facilities based on the scores.

2.2 Locating Marked Crossings

Problem Statement. A number of pedestrian-vehicle collisions occur at locations at which there is no marked crossing. The issue is in determining where marked crossings should be located, and what the spacing should be between crosswalks.

Literature Review. Jones and Tomcheck (2000) found that the removal of marked crossings from uncontrolled intersections resulted in a 61 to 73% reduction in the number of pedestrian-vehicle collisions at those locations. (An uncontrolled intersection is where there is no signal or stop sign on the road that the pedestrian must cross). Their study considered 104 uncontrolled intersections in Los Angeles, California, at which crosswalks had been removed between 1982 and 1991. Their study essentially verified the finding of Herms (1972), who stated “twice as many pedestrian accidents occur in marked crosswalks as in unmarked crosswalks.” Neither study suggested that pedestrians were “safer” by crossing at unmarked locations, although many readers have made such an inference. Smith and Knoblauch (1987) emphasized that Herms’ study had been frequently misquoted. The authors also suggested that the differences between Herms’ marked and unmarked crossings (which he compared in terms of their crash rates) were not recognized in the study. For example, the marked crossings that Herms studied were more heavily used by children and the elderly – pedestrians from these groups have been shown to be more prone to being struck by motor vehicles than pedestrians in other age groups, regardless of the crossing location or the presence of a marked crosswalk. In fact, child and elderly pedestrians were observed to go out of their way much more regularly than other pedestrians to use marked crosswalks. The authors developed a set of guidelines for marked crossings which have since been updated by Zegeer et al. (2001), as reported below.

Yagar (1985) reported on Toronto, Ontario’s 700 “pedestrian crossover” installations. These crossovers were marked crossings placed at uncontrolled locations at which signalization was not warranted. The finding was that the number of pedestrian-vehicle incidents increased over a 10-year period that enveloped the five years before and five years after the introduction of the crossovers. A deeper examination revealed that the incident increases were primarily because of the heightened crossing involvement of non-residents, particularly on weekdays. The number of incidents involving city residents, and the number occurring on weekends, all decreased. The author’s finding suggested that non-residents, because of their lack of familiarity with local driver behavior, traffic control practices and “rules of the road,” may in general be more susceptible to involvement in pedestrian-vehicle collisions than residents.

Roughail (1984), in a survey of pedestrian-vehicle conflicts at ten locations in Columbus, Ohio reported that midblock crossings were generally unexpected by motorists. The negative impacts of this unexpectedness on pedestrians were compounded by higher midblock travel speeds (than at intersections) and sight distance restrictions resulting from on-street parking. The author also reported that conflicting interpretations existed as to who had the right of way at any given time, particularly when traffic control was absent. Some jurisdictions, for example, were giving the pedestrian the right-of-way at uncontrolled crossings, yet prohibiting pedestrians from leaving the curb when vehicles are approaching. The author also noted that very few midblock locations met the MUTCD pedestrian warrants for a traffic signal, as reported below (although the author’s finding was based on an earlier edition of the MUTCD).

The *Manual on Uniform Traffic Control Devices* (MUTCD 2003) provides warrants for pedestrian signals. Many jurisdictions use the warrants to indicate the need for a marked crossing, as would be an output of the MUTCD's recommendation for a pedestrian signal. The Institute of Transportation Engineers has developed guidance for midblock crossing installations. Midblock crosswalks are recommended:

- Where a significant number of pedestrian crossings and pedestrian-vehicle conflicts exist;
- Where the crossing can concentrate or channel multiple pedestrian crossings to a single location;
- At approved school crossings along safe walk-to-school routes;
- Where adjacent land uses generate high concentrations of pedestrians who need to cross – such land uses might include retail and recreational developments, and transit stops;
- Where pedestrians need delineation as to the “optimal” place to cross;
- Where there is adequate sight distance for a crossing – obstacles such as street furniture, vegetation and on-street parking may need to be removed to provide adequate sight distance; and
- Where an engineering study indicates the need for such a crossing away from the nearest stop sign or traffic signal.

Midblock crossings are *not* recommended:

- Immediately downstream (less than 300 ft) of a traffic signal;
- Within 600 ft (183 m) of another crossing location, except in downtown areas and where there is a well-defined need;
- On streets with speed limits above 45 MPH (72 KPH).

Extensive research by Zegeer et al. (2001) compared the five-year crash histories at 1,000 marked crossings with those at 1,000 unmarked crossings in 30 U.S. cities. The city locations spanned the country, and included Salt Lake City. The authors found that the pedestrian volume, the AADT, the number of lanes, and the presence of a raised median were all associated with pedestrian-vehicle crash occurrence. Also, pedestrians aged 65 and over were overrepresented among crash victims. The study did not consider school crossings, so the crash involvement of children was not examined. The following variables did not have a significant effect on pedestrian-vehicle crash rates: the adjacent land use, the location along the roadway (intersection, midblock), the speed limit, the condition of the crosswalk marking, and the crosswalk marking pattern. Regarding the nonsignificance of speed limit, the authors noted that pedestrians may be “more careful” when crossing high-speed roads than in crossing other roads. The authors developed the following recommendations:

- Marked crossings are *not* recommended at uncontrolled locations on multilane (4-or-more lane) roads where the traffic volume exceeds 12,000 per day *and* there is no raised median, or 15,000 vehicles per day with a raised median.
- Similarly, marked crossings are *not* recommended without enhancements at uncontrolled locations on three-lane roads (a two-way left turn and two travel lanes) along which the daily traffic volume exceeds 12,000, *unless* the speed limit is low.
- Marked crosswalks at uncontrolled locations on roads along which the speed limit exceeds 40 MPH are not recommended *unless* the crossing is supplemented with enhancements.
- Marked crossings on two-lane roads with fewer than 12,000 vehicles per day *may* have neither a positive nor a negative effect on pedestrian safety.
- At any uncontrolled location, providing a marked crosswalk *only* will do little to enhance the safety of pedestrians; additional improvements such as warnings, flashers, upstream markings, and so forth are needed.

- A high priority should be placed on providing marked crosswalks where the pedestrian volume exceeds 20 per peak hour (or 15 elderly or child pedestrians per peak hour).

An “enhancement” to a marked crossing includes supplemental or special markings and patterns, signing, and safety devices.

Portland, Oregon. Use a midblock crosswalk where there is a demand for crossing and where there is no nearby marked crosswalk. Use ladder pavement markings, and accompany with signing to warn drivers of the crosswalk. Consider a crossing prohibition under only very limited circumstances, such as where crossing would be dangerous for pedestrians, the sight distances for pedestrians or motorists are obstructed, where crosswalks are numerous enough to conflict with traffic flow, particularly where there are multiple offset or “T” intersections, and in unique situations.

Florida. Provide crosswalks at all signalized intersections (across all legs) and at all signalized midblock locations. An unsignalized, midblock crossing may be inappropriate where the speed limit is 40 MPH or more, or where sight distance is limited. An engineering study is recommended for crosswalks at uncontrolled locations. A marked crossing is recommended where there are more than 25 pedestrians per hour or recurring pedestrian-vehicle conflicts. A marked crossing is needed to reach a porkchop refuge island (channelizing island) when the product of pedestrians and right-turning vehicles exceeds 800 per hour. Crosswalks are not recommended at (uncontrolled) locations having low levels of pedestrian-vehicle conflict. Avoid placing crosswalks immediately downstream of bus stops, traffic signals, and other marked crossings. Crosswalk separation distances may be as little as 500 ft when pedestrian volumes warrant. At skewed intersections, it is recommended that crosswalks “follow the skew,” staying within 0.6 m (2 ft) of the lateral lines of the highway. Consider sight distances when placing crosswalks on horizontal or vertical curves; on vertical curves, placement at the crest is desirable. When sight distances are limited, use traffic calming measures to reduce motor vehicle speeds.

New Jersey. Provide crosswalks at all signalized intersections with pedestrian signal heads, all locations at which a school crossing guard is normally stationed, and all intersections and midblock locations satisfying minimum criteria in the MUTCD. The need for a crosswalk should be determined on a “leg-by-leg” basis, such that a crosswalk may be warranted on one side of an intersection but not the other. A crosswalk should also be provided where a dedicated pedestrian trail crosses a highway at a midblock location, where pedestrian traffic would not otherwise be anticipated, and where development on both sides of the highway results in concentrated pedestrian volumes crossing the highway where there is no intersection.

Washington. Marked crosswalks are to be provided at all signalized intersections having pedestrian indications, all locations at which a school crossing guard is stationed, all intersections and midblock locations that satisfy minimum vehicular volume, minimum pedestrian volume, and other basic criteria, and all other locations at which there is a need to clarify the preferred crossing location. The marked crosswalk criteria are as follows:

- The speed limit is less than or equal to 45 MPH;
- Adequate stopping sight distance exists;
- The block length, for a midblock crossing, is at least 600 ft; and
- There are “minimal conflicting attention demands.”

The cities of Bellevue and Kirkland (both of which are in Washington) have developed the following additional criteria for marked crossings:

- The crossing is part of a walk-to-school route;
- The crossing is a member of a route identified in the city's nonmotorized plan;
- The crossing provides a connection to a major retail development;
- The crossing provides a "significant benefit" to transit;
- The distance to a "better" crossing is more than 300 ft;
- A majority of the people who cross (or who would cross?) have a "more difficult than average" experience in crossing the street;
- There is an opportunity to concentrate pedestrian crossings at one location.

Discussion. It is evident that some controversy and confusion exist over the effectiveness of marked crosswalks, particularly at uncontrolled locations. The findings of Herms (1972), Jones and Tomcheck (2000), and others, that crosswalks appear to compromise the safety of pedestrians, do not give mention to crosswalk enhancements or crosswalk location criteria. The guidelines of the agencies discussed above, along with those of Zegeer et al. (2001), are clear on where crosswalk markings should be established. It is possible that earlier crosswalk markings were not established based on a scientific approach. The proposed guidelines represent a combination of the criteria discussed above.

Example Guidelines. *Crosswalks should generally be marked on all legs of a signalized intersection. Also, crosswalks should generally be marked on all legs of a four-way stop controlled intersection. A crosswalk might not be marked across a leg of a controlled intersection when walking routes, field conditions or adjacent development attributes do not support a marked crossing. At an intersection at which the road that the pedestrian must cross is not controlled, then apply the midblock crossing criteria discussed below. At midblock locations, three options must be considered: no crossing, a marked crossing, and a grade-separated crossing. Midblock crosswalks are recommended when:*

Two-lane roads

- *The speed limit is less than 45 MPH, AND*
- *Adequate stopping sight distance exists, AND*
- *The anticipated pedestrian volume is at least 20 per peak hour, or at least 15 elderly and child pedestrians per peak hour, OR*
- *A bus stop is adjacent, OR*
- *The crossing is along a safe walk-to-school route, AND*
- *The distance to the nearest marked crossing is more than 300 ft.*

Three-lane roads and four-or-more lane roads with no raised median

- *The speed limit is less than 45 MPH, AND*
- *Adequate stopping sight distance exists, AND*
- *The anticipated pedestrian volume is at least 20 per peak hour, or at least 15 elderly and child pedestrians per peak hour, OR*
- *A bus stop is adjacent, OR*
- *The crossing is along a safe walk-to-school route, AND*
- *The distance to the nearest marked crossing is more than 300 ft, AND*
- *The average daily traffic volume is less than 12,000.*

Four-or-more lane roads with raised medians

- *The speed limit is less than 45 MPH, AND*
- *Adequate stopping sight distance exists, AND*
- *The anticipated pedestrian volume is at least 20 per peak hour, or at least 15 elderly and child pedestrians per peak hour, OR*

- *A bus stop is adjacent, OR*
- *The crossing is along a safe walk-to-school route, AND*
- *The distance to the nearest marked crossing is more than 300 ft, AND*
- *The average daily traffic volume is less than 15,000.*

If the pedestrian volume warrants listed above are not met, or in the absence of reliable pedestrian volume data, then a midblock crossing should be considered if a connection would be provided to a major retail, employment, industrial, recreational, or parking development. Each midblock crosswalk should be enhanced with illumination, piano- or ladder-style markings, advance signing for drivers, and guidance for pedestrians. Overhead or in-pavement flashers that are activated when pedestrians are present should also be considered. A raised crosswalk should be considered if the crossing is within an area in which traffic calming is desired. If the pedestrian volume, bus stop or school route warrants are met AND adequate stopping sight distance is NOT provided, then consider the installation of a signalized midblock crossing. Alternatively, consider a pedestrian crossing prohibition. Criteria for grade-separated pedestrian crossings are discussed later in this document. The research team identified a number of fatal and recurrent pedestrian-vehicle crash sites at which a marked crossing may be warranted.

2.3 Pedestrian Refuges

Problem Statement. A number of pedestrian-vehicle collisions have occurred in Utah because, once in the roadway, a pedestrian must “commit” to a crossing at which there is no place of refuge in the roadway’s center. This is a particular concern in crossings of wide, multilane streets. It can be argued that a raised median in these circumstances *may* have provided a temporary “sanctuary” for a crossing pedestrian who would have otherwise been exposed to passing motor vehicles.

Literature Review. Ribbens (1996) noted that “the installation of well-designed pedestrian refuge islands at selected places on multilane roads and at hazardous road sections can be beneficial to pedestrians to cross roads safely.” He described the refuge island as “assisting” pedestrians, particularly the elderly, infirm and children, in crossing multilane roads at midblock locations and at complex intersections. Moore and Older (1965) pointed out that crossings with refuges were “much safer” than those without. Bowman and Vecellio (1994) recognized the benefits of medians for pedestrian safety and operations, while noting that it was difficult to quantify the benefits. Similarly, King et al. (2003) acknowledged the benefits, noting that a raised median along a suburban road in central New Jersey was associated with a 2 MPH decrease in the 85th percentile of motor vehicle speeds and 28% decrease in pedestrian exposure risk. These authors suggested that the benefits of a raised median could be quantified by comparing its cost with the savings from a reduction in collisions.

Portland, Oregon. Use when the roadway to be crossed is greater than 15 m (50 ft) or more than four lanes in width. An island can be used where there is a shorter width if it is necessary to “create” longer gaps in the traffic stream.

Florida. A median refuge island is recommended whenever the crossing distance exceeds 18 m (60 ft). The median width should be at least 2.4 m (8 ft). Medians may be needed on 4-lane collector roads, in addition to arterials.

New Jersey. Provide a median with a pedestrian refuge area wherever the crossing distance exceeds 18 m (60 ft). Install pushbuttons in the median, along with wheelchair ramps or a full cut. Provide a median at all midblock crossings and unsignalized intersections along multilane highways. A median at least 2.4 m

(8 ft) in width should be included along all new or reconstructed arterial or collector highways having four or more lanes. The refuge island should not be less than 3.6 m (12 ft) in length. A refuge island width of less than 1.8 m (6 ft) is not recommended, as a feeling of isolation and uneasiness can be created in the pedestrian in the proximity of moving vehicles.

Washington. Medians or refuge islands are recommended whenever crossing distances exceed 60 ft (18.3 m) to provide a waiting and resting area for “slower” pedestrians. Medians or refuge islands are recommended along collectors that are “long” and that handle heavy, high-speed traffic. Illumination of medians and refuges is recommended.

Discussion. The prevalence of wide streets in Utah is such that a large number of facilities meet the Portland, Florida, New Jersey and Washington requirements for medians and pedestrian refuges. It may be impractical to “retrofit” existing roads in Utah with raised medians that are wide enough to serve as pedestrian refuges. The extent of retrofitting that would be involved is unknown, however. Field investigations were made of 294 pedestrian-vehicle collision sites. A total of 153 of the collisions occurred at crossings of four or more lanes of traffic. Of these 153 locations, only 17 (11%) featured a raised median that could serve as a pedestrian refuge. The finding is that raised medians are widely lacking at pedestrian-vehicle collision sites in Utah. Strong consideration should therefore be given to raised median retrofitting.

The guidance in use on pedestrian refuges is based on the crossing distance: three of the four agencies studied for this report were using 18 m (60 ft) as the minimum crossing distance requiring a refuge. The guidance does not consider several other important factors, including the traffic volume and motor vehicle speeds. Further study would be needed to incorporate these factors into pedestrian refuge guidelines. It may be possible, by incorporating the other factors, to refine the guidelines such that only a subset of wide roads meets pedestrian refuge “warrants.”

Example Guidelines. *In the interim, experiment with the following guidelines for all NEW and RECONSTRUCTED roads in Utah:*

- *Include a raised median at all locations where the crossing distance equals or exceeds 18 m (60 ft).*
- *The median should be at least 2.4 m (8 ft) in width and 3.6 m (12 ft) in length to provide proper service as a pedestrian refuge.*
- *The median should be illuminated to provide nighttime visibility for motorists and pedestrians.*
- *Tactile devices should be incorporated into the median to provide guidance for visually-impaired pedestrians.*
- *Provide wheelchair access to the median at marked crossings. For a wide median (3.6 m or 12 ft or more), provide ramps on either side at a maximum slope of 1:12; for a narrow median (less than 3.6 m or 12 ft), cut an at-grade path of a width of at least 0.9 m (3 ft) into the median.*

In the future, guidelines for pedestrian refuges should be developed. Criteria should be developed for crossing distance, traffic volumes, and motor vehicle speeds. Existing guidelines for pedestrian refuges are based on crossing distances only; there is a need for further research in this area. The new pedestrian refuge guidelines should be considered for implementation, perhaps through retrofitting qualifying roads with raised medians.

2.4 Pedestrian Crossing Enhancements

Problem Statement. The research team observed that most of the crosswalk markings at recurrent pedestrian-vehicle crash sites were of the standard, transverse dual white stripes form. In many cases, the markings were faded and poorly visible. In addition, the visibility of standard crosswalk markings – whether faded or freshly-laid – can be affected by lighting conditions, sight distance and various distractions within the range of driver vision. Further, a motorist may not be attentive to the *usage* of a crosswalk, particularly if pedestrian crossing volumes are not high. Given that pedestrian visibility is essential to the safety of crossings, it is important that crosswalk markings be prominent to approaching motorists.

Literature Review. Van Winkle and Neal (2000) reported on a crossing problem in Chattanooga, Tennessee. Local residents were angered over the lack of a traffic signal at an intersection of a minor side street with a busy arterial. The volumes at the intersection did not meet any of the MUTCD traffic signal warrants. The City elected to install advance and intersection flashers that would flash *only* in the presence of a crossing pedestrian. The flashers were actuated by a pedestrian pushbutton. An improvement in motorist yielding to pedestrians was observed at the intersection. The authors reported that several cities – Alvin, Texas, Austin, Texas, Federal Way, Washington, Fort Collins, Colorado, Topeka, Kansas, and others – had installed one or more in-pavement crosswalk flashers, all with success (although no formal studies had been conducted). The City of Kirkland, Washington had installed passive-activation in-pavement crosswalk flashers in 16 locations. Yielding to pedestrians by drivers was observed to increase from 16 to 65% “before” to 85 to 100% “after” installation. The City of Santa Rosa, California found that overhead flashers were more effective than in-pavement flashers at crosswalks.

Miller and Dore (undated) reported that, as of the year 2000, there were about 100 installations of in-pavement flashers, with most of them in cities in California and Washington. The authors recommended their application on multilane roadways at crossings where pedestrian usage is moderate. Undivided roadways (i.e., no median) in downtown, commercial, or other densely-developed areas may be the most appropriate settings. The authors noted that the devices might not be effective along high-speed, multilane roads, particularly where pedestrians do not regularly cross. Agencies that had installed flashers described the following concerns: highway users are uncertain if the flashers work since most are activated only by a pushbutton, some pedestrians are unfamiliar with how the flashers are activated, some pedestrians do not use the pushbutton, some motorists do not respond by slowing and stopping, and yellow flashers do not convey a drivers-must-stop message. Regarding the latter, the authors hypothesized that red flashers might serve as a stronger indication to drivers that they must stop.

Kannel et al. (2003) reported on the effectiveness of in-street STATE LAW – YIELD TO PEDESTRIAN signs. These signs are installed at ground level in the center of the road, regardless of the presence of a raised median, adjacent or along the centerline of a crosswalk. The authors examined applications in Portland, Oregon, Madison, Wisconsin, Michigan State University, cities in New York, and Cedar Rapids, Iowa. The signs were generally credited with increasing the yielding behavior of drivers to pedestrians, although the results varied by location. In Madison, the percent of drivers yielding increased from 10% before to 20% after the signs were placed; in Portland and New York, yielding increased from 62% before to 81% after. At Michigan State, yielding increased “substantially;” also, drivers were observed to return to their “normal habits” once the signs were removed. The authors noted that the sign did not have a significant effect on yielding when the drivers were faced with competing demands for their attention, such as high turning volumes. Prior research had found that signs made of a durable, flexible plastic and either held in place by ballast or bolted into the pavement were superior to other designs; the superiority was in the ability of a sign to return to its original position after being struck. Sign placement was nonetheless an issue; left-turning vehicles in particular were prone to hitting a sign in Cedar Rapids, Iowa, suggesting that placement outside of turning paths and adjacent to (not in) a crosswalk would be useful.

Huang et al. (1996) reported on enhancements installed directly overhead at crosswalk locations. In Seattle, Washington, a CROSSWALK sign was installed on a mast arm over a crosswalk. Motorist yielding behavior increased from 45.5% before to 52.1% after installation. In Tucson, three locations were outfitted with overhead fiber optic signs that displayed the message STOP FOR PEDESTRIAN IN CROSSWALK upon activation by a pushbutton. The signs were supplemented with an overhead PEDESTRIAN CROSSING sign. Each of three crossings was uncontrolled and did not meet the warrants for a traffic signal. Collectively, motorist yielding behavior decreased from 62.9% before to 51.7% after the signs were installed. The authors concluded that the low-cost, low-technology approach used in Seattle was the most effective of those studied. None of the approaches appeared to modify pedestrian crossing volumes, but pedestrian crossing aborts, hesitations, and dashes decreased under all treatments.

Portland, Oregon. Use a raised crosswalk or intersection in very limited cases in which special emphasis on pedestrians is desired.

Florida. Use a raised crosswalk where pedestrian volumes are high; illuminate the crossing.

New Jersey. Although traffic calming is given an extensive discussion, treatments that are specific to pedestrians are not addressed in this agency's guidelines.

Washington. Seven different crosswalk marking patterns can be used, as follows:

- Horizontal Bars: These consist of two, parallel transverse stripes. These are commonly used at stop-controlled intersections. They are easy to install and maintain, although they wear rapidly, and are not as visible as some of the other marking patterns. They are inappropriate for midblock locations.
- Zebra: White stripes are marked diagonally within the space of the crossing. These are highly visible, but the surface can be slippery, and a high level of maintenance is required.
- Ladder Bar: White stripes are marked longitudinally within the space of the crossing. These are highly visible, but the surface can be slippery, and a high level of maintenance is required.
- Piano: These are similar to the ladder bars, except that the stripes are widely spaced. They are highly visible, and the maintenance can be low if the longitudinal stripes are positioned outside of the wheel paths.
- Dashed – European: The horizontal bars are dashed rather than continuous. These “capture attention,” but do not, perhaps, “define space” as well as the other patterns.
- Solid: The entire crosswalk is solid white. These are highly visible, but can be slippery and require a high level of maintenance.

The Northwest Region of the state of Washington had established an interim policy to use the piano pattern, referred to as the “non-symmetrical piano key” layout (see Figure 3). Specifications for the crosswalk are as follows:

- Use white-colored marking materials only.
- The preferred line width is 24 in; a 24-in line width is required at midblock crossings.
- A sequence of 12-in width line pairs may be used for traffic lane widths of 12 ft or less.
- Provide a stop line 4 ft in advance of the crosswalk.

Raised intersections may be appropriate in urban centers and downtown areas where traffic is “already moving slowly” through intersections. Special tactile treatments or audible warning signals must be added to make these locations detectable to the visually impaired. A raised, midblock crosswalk is suitable on low-speed, low-volume local streets.

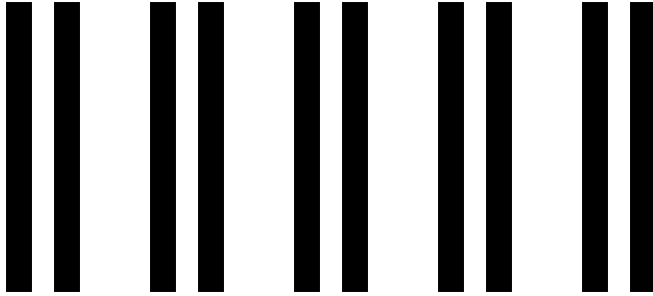


Figure 3. Non-Symmetrical Piano Key Crosswalk Layout

(Note: Each piano key is 8 ft in length; each pair is spaced at 4 ft center-to-center; within each pair, the keys are spaced at 2 ft. The width of each key is 8 in. The markings would actually be white in practice; black is used here to provide contrast.)

Discussion. Little guidance is available on the type of marked crossing pattern to use in a given situation. One of the few definitive findings is that standard, transverse stripes (horizontal bars) are inappropriate for midblock crossings. The Northwest Region in Washington had elected to use the non-symmetrical piano key crosswalk pattern. Salt Lake City had developed a variation on the ladder bar layout, in which a center strip (transversely) had been removed (“double ladder?”) to enable pedestrian traction during periods of rain and ice. There is also little information on the pedestrian safety impacts of various crosswalk marking patterns. It is clear, though, that zebra (referred to in the MUTCD as diagonal), ladder bar, piano and solid crosswalk patterns are more visible than standard and dashed patterns. The research team did not have information on the visibility of Salt Lake City’s double ladder. The ladder bar pattern was reserved by UDOT for school crossings only. The MUTCD recommended that diagonal (zebra) lines oriented at a 45° angle to the longitudinal and transverse directions be used for added visibility.

Similarly, limited guidance is available on in-pavement or overhead crosswalk flashers. The MUTCD approves of the usage of in-pavement crosswalk flashers; the flashers are not to be installed at yield-, stop-, or signal-controlled intersections. Salt Lake City installed an in-pavement flasher adjacent the Gallivan Center at 200 South and Regent Street (40 East) in the fall of 2001. The impact of the device on pedestrian safety has not yet been fully determined, nor have the City’s plans for additional applications. The City’s observations were that many pedestrians were not using the pushbuttons to activate the flashers; the crossing’s technological capabilities were, thus, being under-utilized. The experience with in-pavement flashers, as reported in the literature, has nonetheless been successful.

Criteria for the installment of raised crosswalks are similar to those for speed humps, with the addition of a minimum pedestrian crossing volume. Speed humps are typically installed along roads where the speed limit is no more than 25 to 30 MPH and the ADT is 500 or more. In Manhattan Beach, a raised crosswalk is used when these criteria are met, the 85th percentile speed exceeds the speed limit by 7 MPH or more, and 25 or more pedestrians cross during the peak hour. Some concern has been expressed by emergency service departments on the effects of devices such as raised crosswalks on response times. Data collected in six U.S. cities and counties indicated that a delay of 3 to 13.5 sec was associated with each “hump” (Ewing 1999). The variation in the delay time depended on the height and width of the hump, and on the type of emergency response vehicle. Most police agencies were in favor of hump devices, while most fire rescue agencies were opposed to them. Compromises had been reached in some jurisdictions by integrating the locations of hump and other traffic calming devices with emergency routing plans. One general approach was to avoid placing humps and tables along primary response routes, thereby reserving them for secondary and tertiary routes. Another approach was to design “split” or “partial” humps that could be circumvented by emergency vehicles. It is not clear how the latter approach would apply to raised crosswalks, though.

The effects of raised crosswalks and other speed hump devices on snow removal has been another concern. Ewing (1999) reported that humps and similar devices were *not* preventing snow removal. The

strategies employed by Dayton, Ohio, Bellevue, Washington, Montgomery County, Maryland, and Toronto, Ontario included the following:

- Mark each hump with an advance warning sign as a reminder to snowplow crews.
- Instruct snowplow operators to travel slowly over humps.
- Use rubber-tipped snowplow blades.
- Place rollers on snowplow blades to allow them to “roll” over humps.
- Use salt applicators to deal with “wedges of snow” that are left on the backs of humps.
- Use a sinusoidal rather than a parabolic hump design, thereby enabling a smooth transition from the pavement surface to the gradient of the hump.

In Minnesota, where ice frequently forms underneath accumulated snow, it is necessary to use steel-tipped, rather than rubber-tipped blades. To protect speed humps from damage, the tips were being outfitted with metal extension “shoes.”

Low-cost, low-technology signing has been effective in a number of applications, although no single device has been successful in increasing the portion of drivers who yield to pedestrians to 100%. Overhead CROSSWALK signs and in-street YIELD TO PEDESTRIANS signs have generally had similar, positive effects on pedestrians and motorists. Fluorescent yellow-green pedestrian crossing signs (MUTCD code W11-2; see cover figure) have been approved for use adjacent crosswalks by the FHWA. Current UDOT policy (and Salt Lake City policy) was to reserve the fluorescent yellow-green color for school crossings. The fluorescent yellow color was available for general pedestrian crossing applications. Clark et al. (1996) found that the fluorescent yellow green signing material produced only marginal improvement in pedestrian-vehicle conflicts at crossings, when compared to standard yellow signing; the fluorescent yellow color was not studied. The authors recommended that additional research, conducted over an extended before-after period, was needed. Regardless of the signing color and retroreflectivity (standard or fluorescent yellow or fluorescent yellow-green), the FHWA recommends that one W11-2 sign be placed upstream of the crossing. Then, to alleviate motorist confusion over the location of the crossing, the FHWA suggests that a second W11-2 sign, with a diagonal downward pointing arrow plaque (W16-7p), be placed immediately adjacent the crosswalk.

Example Guidelines. *There are four forms of crosswalk enhancement: crosswalk patterns, crosswalk signing, in-pavement flashers, and raised crosswalks. The following discusses example guidance for each enhancement:*

Crosswalk Patterns. *Consider using the non-symmetrical piano key crosswalk pattern because of its improved visibility compared to the standard dual transverse stripes. Alternatively, consider using the double ladder bar variation developed by Salt Lake City. The example guidance refers to broad applications that are not limited to school crossings. If the piano keys are striped outside of the wheel paths of motor vehicles, then the crosswalk’s maintenance needs can be minimized. Use wide piano keys where traffic lanes are wide; reduce the widths of the keys as the lane widths decrease. Further study of the effectiveness of the piano key and other crosswalk patterns is needed.*

Crosswalk Signing. *If the crosswalk is at an uncontrolled location that is not raised or does not feature in-pavement flashers, install the following signs at each crosswalk:*

- Overhead CROSSWALK sign OR
- In-street YIELD TO PEDESTRIANS sign AND
- Standard or fluorescent yellow Pedestrian Crossing sign AND
- Advance Pedestrian Crossing sign on all approaches to the crosswalk

While an advance Pedestrian Crossing sign should be placed on the approach to ALL crosswalks at uncontrolled locations, different types of signing would be needed at raised crosswalks and at crosswalks with in-pavement flashers.

School crossings should continue to be addressed according to Utah Administrative Code, Title R920-5: Manual and Specifications on School Crossing Zones – Supplemental to Part VII of the Manual on Uniform Traffic Control Devices. The proposed crosswalk enhancements discussed in the current document should be considered for school crossings, particularly if the crossing sees regular usage during non-school hours or is not served by a crossing guard.

***In-Pavement Flashers.** Install in-pavement flashers at uncontrolled, marked crossings of multilane roads having no raised median and moderate pedestrian volumes. Ideally, the flashers should be automatically activated in the presence of a crossing pedestrian. In the absence of pedestrian sensor technology, and possibly as a reduced-cost approach, pedestrian pushbuttons should be used to activate the flashers. Instructional signing for pedestrians should be provided adjacent the pushbutton. The guidance should emphasize that the crosswalk will flash if (and only if) the pushbutton is pressed. Drivers should be provided with advance warning signs of a “flashing” crosswalk. A low-profile, snowplow-resistant flasher head should be used. To minimize maintenance needs, consider a design that is not prone to dirt accumulation within the housing of each flasher.*

The research team identified several marked crossings at uncontrolled locations that would meet the criteria for in-pavement flashers (using pedestrian-vehicle crashes as a surrogate for pedestrian volumes). Each of these crossings was either a recurrent or fatal pedestrian-vehicle crash site during the 1992-2001 study period. The crossings are listed in Table 2. The research team also identified a number of fatal and recurrent pedestrian-vehicle crash sites with no marked crossing. A subset of these sites may be candidates for marked crossings. The research team did not perform the analysis needed to develop a list of example sites; such an effort would be a subject for further study. Once identified, a number of the newly marked sites might meet the criteria for in-pavement flashers.

***Raised Crosswalks.** Implement raised crosswalks along streets in combination with a neighborhood speed management program. Consider installing raised crosswalks along streets where the speed limit is 30 MPH or less, the ADT is 500 or more, and 25 or more pedestrians cross during the peak hour. A substitute criterion for pedestrian volumes might be pedestrian-vehicle crashes; isolated incidents, however, might not identify proper crossing locations. A need to control motor vehicle speeds, based on data indicating that the 85th percentile speed is 5 MPH or more above the limit, should be associated with the installation of a raised crosswalk. The pedestrian volume criterion may be relaxed if there are significant numbers of children, disabled, or elderly pedestrians. In general, avoid placing raised crosswalks along primary emergency vehicle response routes. Install a RAISED CROSSWALK warning sign in advance of and at the crossing. Instruct snowplow operators to travel slowly over all raised crosswalks. Outfit snowplow blades with protective rubber, rollers or “shoes” to avoid damaging the crosswalks.*

2.5 Guidance for Pedestrians at Crossings

***Problem Statement.** Several research studies have found that pedestrians are not always clear on the meaning of pedestrian signal indicators, where or when it is safe to cross, or other aspects of crossing. Guidance for pedestrians at crossings may serve to alleviate situations that could result in conflicts or incidents with motor vehicles.*

Table 2. Selected Crosswalks Meeting the Example Criteria for In-Pavement Flashers

City or CDP	Crossing Location	Through Lanes	Speed (MPH)
American Fork	Main Street at 200 West	4	30
Bountiful	US 89 at 3200 South	4	45
Brigham City	Main Street midblock: Forest Street-100 South	4	30
Canyon Rim	3300 South at 2940 East	6	40
Clearfield	State Street at Clearfield Mobile Home Park	4	45
Grantsville	Main Street at Center Street	4	35
Ogden	Monroe Avenue at Ogden River Parkway	4	40
Provo	300 South at 400 East	4	30
Salt Lake City	600 North at 1100 West	4	35
Salt Lake City	100 South at 1000 East	4	30
Salt Lake City	100 South at 600 East	4	30
Salt Lake City	200 South at Rio Grande Street (440 West)	4	30
Salt Lake City	2100 South at 800 East	4	30
Salt Lake City	900 West at 700 South	4	35
Salt Lake City	State Street at Exchange Place	6	30
Wendover	Wendover Boulevard at Wildcat Way (400 East)	4	35

The following locations were not checked in the field for the presence of a marked crosswalk. If the location features a marked crosswalk, then it meets the example criteria for in-pavement flashers.

Ephraim	100 North at 300 East	4	35
Green River	Main Street midblock: Clarke Street-Solomon Street	4	40
Nibley	Main Street at 2900 South	4	?
Pleasant Grove	State Street at 820 South	4	40
St. George	Bluff Street at 900 South	4	45

Each of the preceding locations features a marked crossing (except for those not verified, as indicated above), multiple lanes, and no raised median.

Literature Review. The MUTCD lists about 22 different regulatory signs that are intended for pedestrians. The signs fall into the following categories (see Figure 4 for examples):

- Prohibitive (R5-10a, b, c; example: PEDESTRIANS PROHIBITED)
- Directive (R9-1, 2, 3, 3a, 3b, 7, 8, 9, 10, 11, 11a, R-10-1, 2a; example: CROSS ONLY AT CROSSWALKS)
- Instructional (R10-3a, b, c, d, e, 4, 4a, 4b; example: PUSH BUTTON FOR GREEN LIGHT)

Informational signs intended for pedestrians are quite common. These exist in a variety of forms and contexts. Criteria for the regulatory signs are described in the MUTCD.

Warning signs that are directed at pedestrians are not discussed in the MUTCD. The FHWA, in its bicycle and pedestrian transportation course, refers to LOOK LEFT and LOOK RIGHT pavement markings in use in Great Britain. These markings are placed in crosswalks at their endpoints, immediately adjacent the curb. The objective of the markings is to remind pedestrians of the direction in which to look before stepping into the crosswalk. The *Florida Pedestrian Planning and Design Handbook* reports on the testing of pavement markings intended to alert pedestrians to search left-right-left before entering the street. The markings “substantially increased” the number of pedestrians looking for traffic; no data were provided. Florida’s *Handbook* also reports on the testing of voice messages reminding pedestrians to search left-right-left. Similarly to the pavement markings, the messages “substantially increased” the number of pedestrians searching for traffic.



Figure 4. Example Regulatory Signs Directed at Pedestrians (R9-3a, R9-2, R10-3)

Portland, Oregon. Avoid prohibiting crossings unless there is a safer crosswalk within 30 m (100 ft) of the “closed” crosswalk.

Florida. A “Use Crosswalk” sign, with a supplemental arrow, is recommended at signalized intersections having high conflicting turning volumes, and at midblock locations. For midblock prohibitions, the signs may have the greatest application when placed in front of schools and other major pedestrian generators. In reference to high conflicting turning volumes, the objective would be to direct pedestrians away from unopposed turns. Use special signs that encourage pedestrians to search “left-right-left” before entering the street. Consider using audio technology at certain crossings to remind pedestrians to look both ways.

New Jersey. (Deviating slightly from signs and markings as the primary forms of communication to pedestrians, New Jersey’s guidelines suggest that colors and symbols can be instrumental in conveying certain messages.) Current MUTCD standards for pedestrian signal heads specify the use of white and Portland orange colors. Symbols should be used rather than words.

Washington. Signing is to be provided at signalized intersections to direct pedestrians to the appropriate pushbutton.

Discussion. Salt Lake City has painted LOOK on the pavement at the extreme ends of crosswalks throughout the city. Eyes and arrows adjacent the LOOK messages remind pedestrians of the direction(s) in which they should search for oncoming vehicles. The response to the markings has been favorable, although there have been no studies of their effectiveness. Guidance for pedestrians, in general, is in the form of pavement markings or signing. Both of these are low-cost strategies that can be widely implemented. Florida reported on successful applications of pavement markings and voice messages. The pavement markings would clearly be less expensive than the voice messages, but the latter also carried the benefit of giving audible warnings to visually-impaired pedestrians.

The research team did not delve deeply into the effectiveness of various colors and symbols in communicating information to pedestrians. Research studies have shown that persons generally react to symbols more quickly than they do to words. The visibility of a given message can vary according to its color, brightness, luminance, reflectance, retroreflectance, orientation, letter size, letter spacing and height (off the ground), as well as the visual acuity of the observer. The color, brightness and luminance of the background are also factors. These visibility factors, separately and in combination, are ripe for research in terms of the effective communication of information to pedestrians (and drivers).

Further research is needed on warning and guiding signs and messages directed at pedestrians. It is unknown, for example, if certain messages are superior to others. It is also not known if pavement

markings have greater impact than signs, or the converse, or if there is any difference at all. It may be useful to consider the development of other types warning signs to aid pedestrians in street crossings. Such warnings might emphasize sight distance restrictions, an estimated crossing time, the minimum distance at which an approaching vehicle should be before starting a crossing, and other aspects of crossing.

Example Guidelines. *The relatively low cost of signing and messages for pedestrians suggest their economic feasibility for implementation on a widespread scale. The effectiveness of various types of signing and messaging are in need of further research, though. A study should be conducted, for example, of the effectiveness of LOOK messages directed at pedestrians. It may be useful to experiment with this and other low-cost strategies to determine their usefulness. Because of the extended period over which pedestrian safety interventions must be evaluated, data intensive studies involving the observation of pedestrian behavior, driver behavior, and pedestrian-vehicle conflicts, both before and after implementation, are suggested. The MUTCD identifies 22 regulatory signs intended for pedestrians. These signs should continue to be installed as per recommendations in the MUTCD. Guide signs adjacent pushbuttons, further discussed in Chapter 3, should continue to be used at pedestrian signals and, if applicable, at in-pavement flashers. Little information is available on the effectiveness of regulatory and guide signs, though. To supplement or augment the regulatory and guide signs, research and innovation is needed on the development of warning signs and messages for pedestrians (in addition to the LOOK message).*

2.6 Pedestrian Crossing Flags

Problem Statement. The research team observed that pedestrian flags established at two different crossings in Salt Lake City and Provo were not heavily used. Also, flag theft has been reported to be a problem. The flags may be effective in improving pedestrian safety, but the level of usage and flag availability are factors.

Literature Review. Research on the effectiveness of pedestrian crossing flags is not extensive. This is partially because of the newness of the flag installation concept; that is, the flags are a relatively new crossing enhancement which have not been around long enough to be fully studied. The City of Berkeley reported on a pilot pedestrian crossing flag program. Flags were installed at seven sites, including two signalized intersections, two uncontrolled midblock locations, two uncontrolled intersections, and one four-way stop controlled intersection. The program lasted for three years (2001 to January 2004). The initial costs of the program were low, but, because of flag thefts, a total of \$10,000 was invested to cover the purchase of 8,000 flags. City staff observed that the flags were used “properly” by only 2% of all crossing pedestrians, and there was no noticeable effect on driver behavior. Flag users were observed to be very careful pedestrians who waited longer to cross than non-flag users. A major local news story was associated with a woman who was hit by a motorist while crossing a street, despite carrying a flag. The City concluded that the program had not been successful, in part because the flags required continual replacement.

Flags were posted at a crosswalk in Charlottesville, adjacent the University of Virginia. A professor observed that few pedestrians used the flags, and that there were occasional thefts. A city manager admitted that, initially, the flag theft frequency was such that complete replacement was needed every other day (Kelly 2003).

An article in the *Urban Transportation Monitor* (2004) reported on the pedestrian cross flag programs in seven U.S. cities, including Salt Lake City and Berkeley. Although two cities had discontinued their programs (Berkeley and Lincoln City, Oregon; the latter because the test site was eventually signalized), five cities confirmed that their programs were welcomed by pedestrians. Salt Lake

City's number of applications, at 142, was the greatest of the cities studied. The article also reported that the FHWA had designated crossing flags as a legitimate traffic control device.

Portland, Oregon. Pedestrian crossing flags are not referenced in this agency's guidelines.

Florida. Pedestrian crossing flags are not referenced in this agency's guidelines.

New Jersey. Pedestrian crossing flags are not referenced in this agency's guidelines.

Washington. The City of Kirkland has experimented with portable orange flags at intersections and midblock crossings. The flags have been used by some, but not all pedestrians. The users of the flags indicate a higher level of comfort when crossing. The flags are viewed as an effective measure to increase driver awareness of an upcoming crossing.

Discussion. A number of cities in addition to those mentioned above have installed pedestrian crossing flags. The experiences of Berkeley and Charlottesville, although somewhat negative, do not necessarily mean that the flags are ineffective. The impact of the flags is most likely dependent on a number of factors, including the crossing location, the ages and crossing behavior of the pedestrians, and the level of understanding of the purpose of the flags by motorists and pedestrians. The Safe Community Coalition of Madison and Dane County (Wisconsin), in its excitement over the introduction of a pedestrian crossing flags program, reported that only one pedestrian injury had occurred at 105 crossing flag locations in Salt Lake City. Although this statistic is promising, it does not indicate what the pedestrian safety record at the 105 locations was *before* the crossing flags were established. A *proper* study of the effectiveness of the flags would involve the following: installation of the flags at locations that had experienced pedestrian-vehicle collisions; inclusion of crossings of various widths, traffic volumes, and motor vehicle speeds; crossings attracting pedestrians of different age groups; a maturation period; and evaluation of the crossing over an extended period. Such a study may find that the crossing flags are more effective at certain locations than at others. Another finding may be that the flags are more prone to theft in certain areas than in others. One finding of the research was that no state agency had established a pedestrian crossing flags program. A number of programs had been established by city governments and community organizations, though.

The effectiveness of the crossing flags can be assessed from at least two perspectives. One perspective is that flags *are effective* in establishing a pedestrian's intent to cross. Dan Bergenthal, Transportation Engineer with the Salt Lake City Department of Transportation and member of the Technical Advisory Committee for this research project, stated in an e-mail message to the research team:

The problem is pedestrian visibility at crosswalks and how to demonstrate (the) intent to cross. The thought is that many drivers justify not stopping for pedestrians by (arguing) that (in a typical situation) the pedestrian really did not want to cross, (but) was just standing "there." Once a pedestrian is holding a flag, (this) excuse can no longer be used – the desire or intent to cross is clear.

The second perspective is that the crossing flags *are not effective* when they are not used. The research team observed pedestrians at two crossings equipped with flags. One crossing was located adjacent the University of Utah campus in Salt Lake City, while the other was located near the Brigham Young University campus in Provo. The cumulative study time was about 2.5 hours. Of the 97 pedestrians who crossed, only nine used the flags. Discounting the 20 pedestrians who arrived at the crossing when no motor vehicles were approaching, then nine of 77 pedestrians (11.7%) made use of the flags. It is likely that a large portion of the pedestrians were university students; researchers (e.g., Moore and Older 1965) have noted that high school and university students are among the least likely pedestrian groups to make "proper" use of pedestrian crossing facilities. Different findings would probably be obtained in observing

crossings at other locations. The rate of crossing flag usage may be greater at a crossing where there is a large number of child or elderly pedestrians.

Example Guidelines. *Given that pedestrian crossing flag programs have been established locally, rather than on a statewide level, with mixed success, a crossing flag program is not suggested at this time. Further study is needed to identify the settings in which the flags would be most successful. Proper settings might include those that are least prone to flag theft, and where the users would be likely to make use of the flags. Upon the identification of these settings, the development of a statewide program might be reconsidered.*

CHAPTER 3.0 Pedestrian Signals

3.1 Available Pedestrian Crossing Time

Problem Statement. A number of pedestrian-vehicle collisions have occurred in Utah when a pedestrian was still crossing a signalized intersection when the conflicting approach received a green signal. Also, a study of pedestrian behavior at signalized intersections in Salt Lake City, conducted as part of this research, revealed that about 4% of all pedestrians could not complete a crossing within the allotted walking person + flashing upraised hand time.

Literature Review. The green time allotted to crossing pedestrians includes the “walking person” and “flashing upraised hand” phases of the signal. The limiting factor in many scenarios is the presence of elderly or disabled pedestrians. The MUTCD recommends a walk (walking person) interval of at least seven seconds, although an interval as low as four seconds can be used if pedestrian volumes and characteristics “do not require” the longer interval. Hoxie and Rubinstein (1994) found that 27% of 592 “older” pedestrians were unable to cross the intersection of Third Street and Fairfax Avenue in Los Angeles, California before the signal on the conflicting approach changed. The average walking speed of these pedestrians was 0.86 m/sec (± 0.17) (2.82 ft/sec ± 0.56). Coffin and Morrall (1995) found that walking speeds of 1.0 m/sec (3.28 ft/sec) at midblock crossings, and 1.2 m/sec (3.94 ft/sec) at signalized intersections represented the 15th percentiles of all elderly pedestrians. The authors’ findings were based on a study of 184 walkers over age 60 at seven locations (six outdoor and one indoor) in Calgary, Alberta. An ELDERLY PEDESTRIANS sign was being used at crosswalks frequented by older pedestrians, although the Coffin and Morrall study did not comment on the sign’s effectiveness. Knoblauch et al. (1996) found a 15th percentile walking speed of 0.91 m/sec (2.99 ft/sec) for elderly pedestrians (age 65 and over). The study considered 3,665 elderly pedestrians at 16 crosswalks at signalized intersections in four urban areas: Richmond, Virginia, Washington, DC, Baltimore, Maryland, and Buffalo, New York. In the same study, the 15th percentile of “young” pedestrians (ages 14 to 64) was found to be 1.22 m/sec (4.00 ft/sec). The authors also found that 85th percentile startup times (incorporating pedestrian reaction and volition) were 3.06 sec for young pedestrians, and 3.76 sec for older pedestrians. Startup times need to be added to walking times to properly determine the crossing time required.

One issue with pedestrian signal timing is the need for integration with motor vehicle signal phases. A number of researchers have discussed the tradeoffs between pedestrian and motor vehicle delays. A full investigation of these studies was beyond the scope of this research. Once a pedestrian green time policy is established, though, it must be evaluated against the effects on motor vehicle traffic operations. A technological development is the PUFFIN (Pedestrian User Friendly Intelligent) signal, which detects the presence of pedestrians in a crossing. A sensor extends the green time until all pedestrians have cleared the roadway. The PUFFIN technology has been tested in Victoria, British Columbia.

Portland, Oregon. Available pedestrian crossing times are not specifically addressed in the city’s guidelines.

Florida. A 4- to 7-sec “walking person” interval is recommended by the MUTCD, but, where possible, provide a longer interval. Allow an additional 1.5 sec for elderly pedestrians to step from the curb into the street. At locations with high pedestrian volumes, allow additional time for pedestrian queue clearance. If a median is available, it is nonetheless recommended that the pedestrian signal provide enough time for the pedestrian to cross the entire street during a single interval.

New Jersey. Where there is inadequate pedestrian walk and clearance time, retime existing and new signals to ensure an adequate crossing time. Signals that are frequently used by the elderly or physically-impaired persons should be retimed to provide a crossing time that is commensurate with their abilities.

Washington. Available pedestrian crossing times are to be designed for the following walking speeds: average pedestrian – 1.2 m/sec (4 ft/sec); older adult – 0.9 m/sec (3 ft/sec); mobility-impaired pedestrian – 0.8 m/sec (2.5 ft/sec).

Discussion. It is evident that three pedestrian groups need to be considered: general (adults, adolescents, children), elderly, and disabled. In general, green times should be designed for the general or “average” pedestrian. The literature recommends that green times be lengthened where elderly or disabled pedestrians regularly cross. There is little guidance, however, on identifying such locations.

Recommendations. *The sum of the walking person and flashing upraised hand times in a pedestrian signal indication should be based on a 3.0-second startup time and a walking speed of 1.2 m/sec (4.0 ft/sec). Where elderly pedestrians are observed or are known to cross, the time should be based on a 3.75-second startup time and a walking speed of 0.9 m/sec (2.95 ft/sec). Where mobility-impaired pedestrians are observed or are known to cross, a walking speed of 0.8 m/sec (2.6 ft/sec) should be used. Guidance in the MUTCD is that a walking speed of 1.2 m (4 ft) per sec should be used to determine the pedestrian clearance time. The MUTCD recommends that a walking speed of “less than 1.2 m (4 ft) per sec” should be considered where slower pedestrians and persons in wheelchairs regularly use the crosswalk. The proper determination of the required crossing time depends on the availability of data on pedestrian ages and physical abilities at the location. Where large numbers of pedestrians cross in groups, the crossing time may need to be extended to account for pedestrian platoon “clearance.” In all cases, the crossing time should be based on clearance of the entire pavement width.*

3.2 All-Red Clearance Intervals During Pedestrian Signal Cycles

Problem Statement. The upraised hand of the pedestrian signals at several intersections visited by the research team was observed to continue flashing during the yellow change interval. The end of the flashing hand phase coincided with the start of the green phase on the cross-street. With no synchronization between the termination of the flashing hand and the beginning of the yellow change interval, there was no way for the pedestrians at these locations to know that their crossing time had expired.

Literature Review. All-red clearance intervals are typically considered in the management of motor vehicle traffic at a signalized intersection. ITE recommends the computation of a change interval between signal phases that may or may not include an all-red clearance interval. That is, the change interval is equivalent to the yellow interval as long as the change does not exceed five seconds; if the change is greater than five seconds, then the excess is allocated to the all-red interval. The ITE equation is as follows (Eccles and McGee 2001):

$$CP = t + \frac{V}{2a + 64.4g} + \frac{W + L}{V}, \text{ where}$$

- CP = change period (sec),
- t = motorist's perception-reaction time,
- V = speed of approaching vehicle (85th percentile, ft/sec),
- a = comfortable deceleration rate of vehicle (ft/sec²),
- g = gradient of intersection approach (%/100),
- W = width of intersection (ft), and
- L = length of motor vehicle (ft).

Some jurisdictions use the third term in the preceding equation as the all-red clearance interval. All-red times are typically between 1 and 5 sec.

Little attention is given in the literature to the benefits of an all-red clearance interval for pedestrians. A pedestrian clearance interval may include the all-red interval if one happens to exist. Allowing the flashing hand to continue during the yellow change or all-red interval, however, is not standard practice. The Pedestrian and Bicycle Information Center (at www.walkinginfo.org) states “a short all-red clearance interval provides a better separation between cars and pedestrians.”

Portland, Oregon. Clearance intervals are not discussed in this agency’s pedestrian guidelines.

Florida. Clearance intervals are not discussed in this agency’s pedestrian guidelines.

New Jersey. Clearance intervals are not discussed in this agency’s pedestrian guidelines.

Washington. Clearance intervals are not discussed in this agency’s pedestrian guidelines.

Discussion. The problem as addressed is twofold. The first issue is the coordination of the end of the pedestrian clearance (flashing upraised hand) interval with the beginning of the yellow change interval for the concurrent green motor vehicle phase. The second issue is the incorporation of pedestrians into the all-red clearance interval, such that a conflicting green phase does not begin until a few seconds after the upraised hand has stopped flashing. The first issue may be a matter of shortening the pedestrian clearance interval such that the upraised hand becomes steady at the same time that the concurrent yellow change interval for motor vehicles begins.

Regarding the second issue, computational formulas for all-red clearance intervals consider intersection widths, motor vehicle lengths, and motor vehicle speeds. Pedestrian walking speeds do not enter into these formulas. The widths of the crosswalks at an intersection may enter into the all-red clearance interval formula, but only as input to the overall intersection width. It is not readily clear how pedestrians should be incorporated into the all-red clearance interval equation.

Example Guidelines. *The MUTCD states that the pedestrian clearance time “may be entirely contained within the vehicular green interval, or may be entirely contained within the vehicular green and yellow change intervals.” The second option is a bit misleading, in that the pedestrian clearance interval could end at the moment that a conflicting green phase begins. To minimize pedestrian-vehicle conflicts in such a case, an all-red clearance interval should be utilized. At many traffic signals, the upraised hand becomes steady when the concurrent yellow change interval begins; then, an all-red clearance interval precedes the start of a conflicting green phase. Assuming that the walking person and flashing upraised hand times are adequate for pedestrian clearance, this practice is probably the most forgiving for someone who is crossing at a signalized intersection. This practice should be considered for regular implementation. Further study of how pedestrians should be incorporated into the computation of all-red clearance intervals is needed.*

3.3 Pedestrian Signal Maintenance

Problem Statement. A pedestrian-vehicle collision at one of the sites visited by the research team may have occurred because the pedestrian signal indication was not functioning at the crossing. At least two other intersections were observed to have either nonfunctioning pushbuttons or a malfunctioning pedestrian signal indication.

Literature Review. The city of Edgewood, Washington recommends that pushbuttons be repaired and maintained as necessary to make them “more responsive” to pedestrians, as discussed in a following

section. The cities of Fremont and Walnut Creek, California, in contrast, appear to have only corrective maintenance policies. Maintenance needs vary according to the materials and design of the pushbutton, wiring, and display components. The California Department of Transportation has established the following maintenance policy for traffic signals; the policy covers pedestrian signals:

A detailed check of the traffic signal should be made at 60-day intervals for proper operation of controller assemblies and signal heads. The 60-day check should include a field inspection that involves a visual check of the indications, pedestrian head alignment, pushbutton operations, and other signal elements. When the word-message pedestrian indications reach the end of their service lives and the indications appear dim, they should be replaced with incandescent symbols.

The Transportation Association of Canada recommends that pushbuttons be inspected every 13 weeks during controller inspections.

Portland, Oregon. No specific guidelines are provided.

Florida. Inspect and maintain pedestrian pushbuttons on a schedule similar to that of vehicular traffic signals. Periodic maintenance of landscaping may be needed to ensure that signal indications remain unobstructed.

New Jersey. Pedestrian signals should be inspected periodically for damage from turning vehicles. The maintenance procedure is to refurbish the signal head, including lens cleaning and bulb replacement.

Washington. Maintain pushbuttons “as necessary” to ensure that they are functioning.

Discussion. The literature and policies of various agencies suggest that pedestrian pushbuttons be inspected every two to three months. It is not clear if these inspection cycles are related to any known data on pedestrian signal malfunctions or deterioration rates. A study of pedestrian pushbutton service lives would probably be useful, including a compilation of data on pushbutton and signal types and repairs.

Proposed Guidelines. *Inspect pedestrian pushbuttons and signal indications quarterly, perhaps as part of a traffic signal controller inspection cycle. Perform visual checks of the indications and manual checks of the pushbuttons. Keep a record of inspections, repairs, and pedestrian signal performance as part of a traffic signal maintenance management system. A study of pedestrian pushbutton service lives would be useful.*

3.4 Pedestrian Signal Enhancements

Problem Statement. Zegeer et al. (1984), among others, reported that pedestrians found little to no benefit in the usage of standard pedestrian signal indications. In particular, the flashing and steady DON'T WALK (i.e., flashing and steady hand) indications (text messages were popularly used at the time of the study) offered only limited information as to how a crossing should be managed. The lack of clear information on crossings may contribute to errant pedestrian behavior, deficient crossing decisions, and conflicts between pedestrians and motor vehicles.

Literature Review. Farraher (2000) reported on the effectiveness of countdown pedestrian indicators (CPIs) in the Minneapolis-St. Paul urbanized area. Studies of six crossing locations involved 372 “before” and 535 “after” observations. The CPIs were effective, apparently, in reducing the portion of pedestrians starting during the flashing hand and still crossing after the steady hand appeared from 6% to

4%. The CPIs were also effective, apparently, in reducing the portion of violators (pedestrians crossing on red) from 15% to 13%. Finally, the CPIs increased the portion of pedestrians who successfully crossed from 67% before to 75% after. Studies of pedestrian actions at 14 intersections with CPIs, located in Salt Lake City, South Salt Lake and Millcreek, were conducted by the research team. The critical findings were that about 10% of the pedestrians arriving on red were violators, and that about 4% of all pedestrians were still crossing at $CPI = 0$ despite starting during the walking man interval. Also, a “kernel” occurred at CPI times between 9 and 11 sec. The kernel represented the range of times over which the transition between “pedestrian crosses” and “pedestrian waits” occurred. Below the kernel, most pedestrians elected to wait; above the kernel, most pedestrians elected to cross. Finally, of those pedestrians electing to start a crossing *during* the countdown interval, 63% were still crossing at $CPI = 0$. The suggestion is that the time remaining provided to pedestrians is not enough information. It is possible that further information, such as an estimated crossing time to which pedestrians could compare the time remaining, might be useful.

Mortimer (1973) confirmed that pedestrians were more likely to have a successful crossing at a signalized intersection when there were pedestrian indications, than when no such indications were provided. Mortimer observed 1,836 pedestrians at eight intersections in Detroit, Michigan. He found that the portion of pedestrians who crossed on the red signal decreased from 25% to 15% upon installation of “ped heads.” In the absence of CPI technology, one approach would be to supplement traditional pedestrian signal indications with signing. Lalani and Baranowski (1993) recommended a sign, established adjacent pushbuttons, with brief explanations of the meanings of the crossing indications (walking man, flashing hand, steady hand). This sign has been established at many crossings since the paper’s publication, and is a UDOT standard. Malenfant et al. (2001) investigated the effectiveness of scanning LED “eyes” in conjunction with the walking man interval. Application of the eyes at eight signalized intersections resulted in reduced pedestrian-vehicle conflicts in all cases. Further analysis was conducted of eyes looking both ways, eyes looking one way (toward the “threat”), steady eyes, and intermittent eyes, but there were no differences between the variations.

Portland, Oregon. Pedestrian signal enhancements are not discussed in this agency’s guidelines.

Florida. Pedestrian signal enhancements are not discussed in this agency’s guidelines.

New Jersey. Pedestrian signal enhancements are not discussed in this agency’s guidelines.

Washington. Pedestrian signal enhancements are not discussed in this agency’s guidelines.

Discussion. Policies on pedestrian signal enhancements appear to be under development. The consensus in the literature is that enhancements are useful to pedestrians. While the meanings of the walking person and flashing upraised hand alone are not fully understood by all pedestrians, they are an improvement over signals that have no pedestrian indications. Enhancements such as CPIs and scanning LED eyes have both been successfully applied. The scanning eyes have not yet been widely implemented, whereas CPIs have been established in a number of cities. Botha et al. (2002), in a review conducted for the City of San Jose, California, admitted that it was difficult to determine the benefits of CPIs in the short-term, since pedestrian-vehicle crashes occur fairly infrequently, mandating that a database be developed over several years. The authors emphasized that a CPI should not be viewed as a solution to pedestrian safety problems, but as one of several mitigating techniques. Salt Lake City initiated the installation of CPIs at intersections in the fall of 2000. As of early 2004, there were about 900 CPIs in the city; other Utah cities had installed CPIs during the interim, as well. Of the 294 recurrent pedestrian-vehicle crash sites investigated for this research, 108 were controlled by a signal. No more than 15 (13.9%) of the intersections had been fitted with CPIs as of year 2003 and 2004 field visits, though. More widespread coverage of CPI-fitted intersections would enable a study of their effectiveness at recurrent pedestrian-vehicle crash sites.

Example Guidelines. *Given that the feedback on countdown pedestrian indicators (CPIs) has been positive, continue to install them at signalized intersections. If it is necessary to prioritize, give top priority to the recurrent and fatal pedestrian-vehicle crash sites identified in this research. These are listed in Table 3. The sites listed, all signalized intersections, experienced either one pedestrian fatality or two or more pedestrian-vehicle collisions between 1992 and 2001. The sites are a subset of all signalized intersections in Utah meeting these criteria; the selected sites tended to have either high severity scores (i.e., fatalities or serious injuries) or more than seven pedestrian-vehicle crashes. Further discussion of the crash sites and the scoring system is found in the Technical Document. Give second priority to signalized intersections along recurrent pedestrian-vehicle crash corridors which are not among those listed in Table 3; these are listed in Table 7, which is found later in this document. Third priority would be given to signalized intersections that feature regular pedestrian activity. Consider a policy that incorporates CPIs and pedestrian indicators into all new traffic signals. In all CPI installations, incorporate the pedestrian green time recommendations presented earlier in this document. The discussion of “Pedestrian Signal Responsiveness” in Section 3.5 offers some related proposals.*

3.5 Pedestrian Signal Responsiveness

Problem Statement. A study of crossings at 14 signalized intersections in Salt Lake City revealed that 10% of all pedestrians who arrived when the signal was red were violators. That is, these pedestrians proceeded to cross when the signal was red. Some of the pedestrians may have violated the signal because of a slow response time following pushbutton actuation. Although delays at signalized pedestrian crossings should be expected, a slow response may be a factor in pedestrian-vehicle crashes.

Literature Review. Huang and Zegeer (2001) suggested that a slowly-responding, actuated pedestrian signal may lead the pedestrian to believe that the signal is not working. The pedestrian may subsequently begin to cross early. The city of Edgewood, Washington recommends that the WALK interval appear within 30 secs of pushbutton activation. Edgewood also recommends the usage of illuminated pushbuttons, similar to those used for elevators, to reassure the pedestrian that his or her signal call has been received by the controller. Sarker et al. (1999) recognized the concerns associated with pedestrian wait times at traffic signals. The recurring event is for a pedestrian to cross against a red signal when an acceptable gap between motor vehicles is perceived. A subsequent occurrence is for the pushbutton to activate the signal sometime after the pedestrian has violated the signal, leading to a potentially needless delay to motor vehicles on the cross-street. The authors proposed a gap-actuated pushbutton signal, in which the pedestrian indication would display as long as an 8-sec (or longer) gap between conflicting vehicles existed. The system required the placement of a vehicle sensor 84 m upstream of the stop line. Simulation studies of an intersection in Utsunomiya City, Japan demonstrated that the average waiting time per pedestrian decreased by 14 sec during the morning peak and afternoon offpeak periods. Little information was provided on traffic volumes, though. Keegan and O’Mahony (2003) reported on a waiting countdown timer that would inform a pedestrian of the amount time left *before* the “walking man” appears. The purpose of the timer was to increase pedestrian compliance at signalized crossings. Tests indicated that the portion of pedestrians waiting for the walking man to appear increased from 65% to 76% after the timers were installed.

Portland, Oregon. When the pedestrian demand is high, it is recommended that pedestrian pushbuttons *not* be used. Traffic signals with regular pedestrian phases are encouraged for use in such areas.

Florida. Assure that the WALK signal appears within a reasonable amount of time after the pushbutton is engaged, preferably within 30 to 60 sec. At midblock crossings, an immediate response is recommended.

New Jersey. Pedestrian signal responsiveness is not addressed in this agency’s guidelines.

Table 3. 108 Signalized Intersections with Recurrent or Fatal Pedestrian-Vehicle Crashes: 1992-2001

City or CDP	Intersection	City or CDP	Intersection
Bountiful	500 West & 400 North ^a	Salt Lake City	300 East & 400 South ^{ab}
Bountiful	500 West & 1500 South ^a	Salt Lake City	300 South & West Temple ^b
Brigham City	Main Street & 100 South ^a	Salt Lake City	300 West & 500 North ^a
Canyon Rim	3300 South & 2300 East ^a	Salt Lake City	300 West & 300 South ^{ab}
Canyon Rim	3300 South & Highland Drive ^a	Salt Lake City	300 West & 400 South ^a
Kearns	4700 South & 4000 West	Salt Lake City	400 South & Main Street ^{ab}
Kearns	4700 South & Dartmouth Dr (4520 West)	Salt Lake City	700 East & 600 South ^a
Kearns	Cougar Lane (4800 West) & Niagara Way	Salt Lake City	700 East & 800 South ^a
Layton	Main Street & Antelope Dr-Syracuse Road ^a	Salt Lake City	700 East & 900 South ^a
Logan	1400 North & 200 East	Salt Lake City	700 East & 1700 South ^a
Logan	Main Street & 100 South ^a	Salt Lake City	700 East & 2100 South ^a
Logan	Main Street & 400 North ^a	Salt Lake City	700 East & 2700 South ^a
Midvale	Center Street & Allen Street-9 th Avenue	Salt Lake City	700 East & I-80 eastbound ramps ^a
Midvale	Husky Hwy & Casa Negra Av (7510 South) ^a	Salt Lake City	900 East & 1300 South
Midvale	Husky Highway at Hillcrest High School ^a	Salt Lake City	900 West & Indiana Avenue (800 South)
Midvale	State Street & 7200 South ^a	Salt Lake City	900 West & North Temple ^a
Millcreek	3300 South & Main Street ^a	Salt Lake City	1300 East & Wilmington Avenue ^a
Millcreek	3300 South & State Street ^a	Salt Lake City	2100 South & 200 East
Millcreek	3300 South & 300 East ^a	Salt Lake City	Highland Dr-1100 East & 2100 South ^b
Millcreek	3300 South & 700 East ^a	Salt Lake City	Main Street & Market Street (340 South)
Millcreek	3300 South & 900 East ^a	Salt Lake City	North Temple & 1460 West ^a
Millcreek	3300 South & 1300 East ^a	Salt Lake City	North Temple & Main Street ^a
Millcreek	3900 South & State Street ^a	Salt Lake City	Redwood Road & 500 South ^a
Millcreek	3900 South & 300 East	Salt Lake City	South Campus Dr-Campus Center loop ^a
Millcreek	4500 South & State Street ^a	Salt Lake City	State Street & Belmont Avenue ^a
Millcreek	4500 South & 500 East ^b	Salt Lake City	State Street & South Temple ^{ab}
Millcreek	5600 South & State Street ^a	Salt Lake City	State Street & Westminster Avenue ^a
Murray	State Street & Vine Street ^a	Salt Lake City	State Street & 100 South ^a
North Salt Lake	US 89 & Center Street ^a	Salt Lake City	State Street & 200 South ^{ab}
Ogden	24 th Street & Adams Avenue	Salt Lake City	State Street & 300 South ^{ab}
Ogden	24 th Street & Monroe Boulevard	Salt Lake City	State Street & 400 South ^{ab}
Ogden	Wall Street & DMV-25 th South ^a	Salt Lake City	State Street & 900 South ^a
Ogden	Wall Street & 36 th South ^a	Salt Lake City	State Street & 1300 South ^a
Ogden	Washington Boulevard & 12 th South ^a	Salt Lake City	West Temple & South Temple ^b
Ogden	Washington Boulevard & 25 th South ^a	Sandy	State Street & 9000 South ^a
Ogden	Washington Boulevard & 26 th South ^a	South Ogden	Harrison Boulevard & 5600 South ^a
Ogden	Washington Boulevard & 27 th South ^a	South Salt Lake	3300 South & 300 West ^a
Ogden	Washington Boulevard & River Drive ^a	South Salt Lake	State Street & Sunset Avenue ^{ab}
Orem	Center Street & 400 West	Spanish Fork	Main Street & 200 North ^a
Orem	State Street & 400 North ^a	Springville	Main Street & 200 South ^a
Orem	State Street & 1200 North ^a	Taylorsville	Redwood Road & 4100 South ^a
Orem	State Street & 1300 South ^a	Taylorsville	Redwood Rd & 4200 South-Mantle Ave ^a
Orem	State Street & Center Street ^a	Taylorsville	Redwood Road & 5245 South ^a
Park City	Olympic Parkway & The Canyons ^a	Taylorsville	Redwood Rd & Murray-Taylorsville Rd ^a
Provo	200 West & 1230 North (Bulldog Blvd)	Tooele	Main Street & 500 North ^a
Provo	500 West & Center Street ^a	Tremonton	Main Street & Tremont Street ^a
Provo	South State Street & 500 South ^a	West Haven	Wilson Lane & 1100 West ^a
Provo	University Avenue & 100 North ^a	West Valley City	2700 West & 3100 South
Provo	University Avenue & University Parkway ^a	West Valley City	2700 West & 3500 South ^a
Roy	5500 South & 4100 West ^a	West Valley City	3500 South & 4000 West ^a
St. George	St. George Boulevard & Main Street ^a	West Valley City	Redwood Rd & Decker Lake Road ^a
Salt Lake City	200 South & 200 East ^b	West Valley City	Redwood Road & 3100 South ^a
Salt Lake City	200 South & Rio Grande Street (440 West)	West Valley City	Redwood Road & 3500 South ^a
Salt Lake City	200 South & West Temple ^b	West Valley City	Redwood Road & Parkway Boulevard ^a

CDP = U.S. Census-designated place (not incorporated).

^a Intersection between one or more state-owned roads; other roads are either city- or county-owned.^b Outfitted with a countdown pedestrian indicator as of 2003 and 2004 field visits.

Washington. Pedestrian actuated signals are recommended at heavily-used midblock bus stops. Increased responsiveness is to be provided during times of peak pedestrian access to (and from) the bus stop. In general, pushbuttons are to be “made responsive” to pedestrians.

Discussion. A pedestrian compliance problem may be associated with slow response times to pushbutton actuation. A waiting countdown timer is a promising addition to pedestrian signals, but it is not known if such timers would completely eliminate pedestrian violations. If the pedestrian signals at an intersection are equipped with CPIs, then a waiting pedestrian can obtain the waiting time by observing the CPI on the cross-street. As long as the cross-street pedestrian signal is displaying a countdown time, an additional waiting timer would not be needed. Making a signal more responsive to the pushbutton would seem to have a stronger impact on compliance than a waiting time, though. The gap-actuated pedestrian signal design proposed by Sarker et al. (1999) is a logical progression in pedestrian signal technology. Their proposal is essentially an extension of adaptive signal control concepts to pedestrians. Further development and testing of the adaptive pedestrian signal is needed. Importantly, the objective of the adaptive signal would not be to preempt the normal signal timing; rather, the signal would work toward minimizing pedestrian waiting times by searching for gaps in cross-street traffic.

Infrared and microwave sensor technology has also been developed to detect the presence of pedestrians. There is no need for a pushbutton when sensors are in place. Little information is available about the costs of this technology, though; also, the technology is considered to be experimental. Guidance from other agencies on *how* to make a pedestrian signal more responsive is limited. Where pedestrian volumes are high, the notion is that at least one pedestrian will be waiting to cross on every cycle. The traffic signals at these locations should be timed to incorporate the pedestrian crossing time into the concurrent motor vehicle green time. Pedestrian volume criteria for pushbutton exclusion have not been clearly delineated, though.

Example Guidelines. *Waiting countdown timers, gap-actuated or adaptive pedestrian signals, illuminated pushbuttons, and pedestrian sensors are all promising technologies that may serve to reduce the number of violations at pedestrian signals. The development of these technologies should be monitored, then considered for implementation if found to be successful. Illuminated pushbuttons may be a low-cost signal enhancement strategy. A waiting countdown timer may not be needed at an intersection that has a CPI, unless there are long intervals during which a countdown time is not displayed. In the interim, pedestrian safety education, proper timing of traffic signals, and enforcement of pedestrian crossing laws should be emphasized. Further research should be conducted on pedestrian volume criteria for exclusion of a pushbutton. When the volume criteria are met, at least one crossing pedestrian might be expected per cycle. In such cases, the pedestrian crossing time should be incorporated into the concurrent motor vehicle green time. Pedestrian signal heads should be used at these locations despite the absence of pushbuttons.*

CHAPTER 4.0 Pedestrian Facility Construction

4.1 Sidewalk Construction and Installation Policy

Problem Statement. Discontinuity or the lack of sidewalks can force pedestrians to walk along the shoulders or edges of roadways. Being in the roadway increases the vulnerability of pedestrians to motor vehicle-related incidents. Further, the crossing behavior of pedestrians is probably affected by the absence of an ordered pathway system. That is, pedestrians may be inclined to cross as they see fit, given the general lack of walking facilities, and despite the potential dangers.

Literature Review. Researchers have examined the effect that the presence of a sidewalk has on pedestrian safety. Ossenbruggen et al. (2001), for example, found that the probability of pedestrian-vehicle crash was two times greater at a site without a sidewalk than at a site with one. Their finding was based on a study of five years of crash data at 87 sites along undivided, two-lane roads in Strafford County, New Hampshire. McMahon et al. (1999) determined that “walking along roadway” crashes were associated with a high speed limit, a lack of wide, “off-road,” walkable areas, and the absence of sidewalks.

Portland, Oregon. Two measures have been developed to identify and prioritize needed pedestrian improvements. The Pedestrian Potential Index (PPI) measures the factors that favor walking, while the Deficiency Index (DI) indicates the criticality of the needed improvements. Application of the PPI involves the designation of certain areas and corridors as “important” for pedestrians. The designations would be made as part of a local or regional transportation plan. Table 4 under “Example Guidelines” (below) presents the factors used to determine the PPI. Table 5 presents the DI. The DI assesses a combination of sidewalk continuity, ease of street crossings, and street connectivity. The ease of street crossings is approximated by the traffic speed, traffic volume, roadway width, and automobile-pedestrian crash totals. Street connectivity is approximated by the length of the street segment.

Florida. All new urban roadway projects are to include sidewalks if pedestrian traffic can be expected. All roadways where pedestrian travel is expected should have a walking area that is out of the vehicle lanes. A separate sidewalk or path is preferred, but a paved roadway shoulder, particularly in rural areas, may serve the need. Efforts should be made to provide direct connections between residences and activity areas such as shopping centers and transit stops. Developers should be required to incorporate sidewalks into every residential, commercial and industrial project. Local jurisdictions should fill in the gaps between undeveloped areas with properly designed sidewalks. Schools should be required to incorporate sidewalks into their sites. Whenever possible, sidewalks should be continued with their full width on bridges. If any part of an accessible route that is within the boundary of a site is part of a public sidewalk or path, then efforts must be made to comply with the requirements of the Americans with Disabilities Act (ADA).

New Jersey. Where a grid or other dense street network is not available, pedestrian “linkages” should be provided to maintain walking continuity. Cul-de-sacs, loop roads and similar treatments that disrupt pedestrian continuity should incorporate pedestrian linkages such as “cut-thrus” to adjoining developments. Large lot commercial developments, such as office buildings and shopping centers, should provide numerous linkages to surrounding residential areas to permit nearby residents to walk to the site. Linkages should also be provided between adjoining commercial, residential and office uses.

Washington. There are no “warrants” for sidewalks. Reference is made to the AASHTO *Policy on Geometric Design of Highways and Streets*, which recommends that sidewalks be developed as integral parts of all city streets. Sidewalks should be constructed if pedestrian activity is anticipated as part of street development. Consideration should be given to connecting adjacent urban communities, even

though pedestrian traffic may be light. In rural and suburban areas, sidewalks are needed at schools, local businesses, and industrial plants that produce pedestrian concentrations. Other appropriate locations for sidewalks might be at parks and office buildings, and in all residential areas. Whenever roadside and land development conditions are such that pedestrians regularly move along a main or high-speed highway, there should be a sidewalk or path. High traffic speeds and an absence of lighting reinforce the need for sidewalks, particularly in rural areas. As a general practice, sidewalks should be constructed along any street or highway that does not have shoulders. Sidewalks constructed along rural highways should be separated from the traveled way by a ditch or other buffer.

Discussion. Sidewalks are being incorporated into all UDOT highway projects where pedestrian traffic would be a “significant factor.” Wheelchair ramps are built into all sidewalks as part of the ADA Ramp Program. Also, UDOT allocates funds under the federally-legislated Safe Sidewalk Program to local governments for the construction of sidewalks adjacent to state routes. The funding allocation formula considers a county’s total population, student population, and pedestrian crash experience. Local agencies must fund at least 25% of the project cost with “their own cash.” Project-related criteria and priorities are established at the local level. In general, there are reactive and proactive approaches to the provision of pedestrian facilities. With the reactive approach, pedestrian facilities are provided where pedestrian-vehicle incidents indicate that there is a need. With the proactive approach, pedestrian facilities are provided as indicated by measures such as Portland’s PPI and DI. The example guidelines consider both approaches.

Example Guidelines. *Continue to incorporate the AASHTO policy by integrating sidewalks into all new street and highway projects. As suggested by the Florida DOT, require all developers to integrate sidewalks into new residential, commercial and industrial projects. Also, consider requesting that local jurisdictions fill in the gaps between disconnected sidewalks and paths.*

For established roadways that do not have sidewalks, the cost of retrofitting may be exorbitant. There are two approaches, both of which are proposed. First, initiate a policy of constructing sidewalks at locations and along corridors that have experienced recurring pedestrian-vehicle collisions. The research team observed that sidewalks were lacking at 23 of the pedestrian-vehicle crash sites visited (see Table 13 of the Technical Document). Second, incorporate the Pedestrian Potential Index (PPI) and Deficiency Index (DI) into the planning of pedestrian facilities. The PPI factors are presented in Table 4. The PPI is the sum of the points scored by all satisfied conditions. A high PPI value is associated with a high potential for walking. The maximum PPI value is 33. More than one condition might be satisfied for a given factor. The PPI designations as presented in the Portland Pedestrian Master Plan are specific to Portland; the conditions in Table 5 have been modified to reflect a more general or “Utah” application. Interpretation of the PPI would need to be developed as part of a pedestrian facilities policy. A geographical display of PPI and DI values as overlays on a street network would be useful to their application. Table 5 presents the DI, which is obtained by summing the scores for the conditions listed. A high DI value is associated with a high pedestrian-related deficiency, thereby indicating a need for pedestrian facilities and improvements. Interpretation of the DI would need to be developed as part of a pedestrian facilities policy. One approach, used by the City of Portland, is to add the PPI and DI scores, then normalize the total according to the length of the street segment being investigated. The normalized scores for various segments can then be ranked for project prioritization.

Table 4. Pedestrian Potential Index (Portland Pedestrian Master Plan)

Factor	Conditions	Points
<i>Transportation Plan Pedestrian Classifications</i>	<i>Pedestrian district</i>	5
	<i>Downtown area</i>	4
	<i>Designated walkway or path</i>	2
<i>Future or “Envisioned” Pedestrian Centers</i>	<i>As designated by the transportation plan</i>	1 to 4
<i>School Proximity Factor</i>	<i>Elementary school radius (1/3 mi)</i>	4
	<i>Middle school radius (1/2 mi)</i>	2
	<i>High school radius (1 mi)</i>	2
<i>Other Destination Proximity Factor</i>	<i>Pedestrian-friendly commercial district</i>	2
	<i>Transit stop seeing frequent use</i>	2
	<i>Public park</i>	2
<i>Combined Metro Environmental Variables</i>	<i>Rating based on land uses, “walk-ability” of destinations, connectivity of street network, and scale of development</i>	1 to 8

Table 5. Deficiency Index (Portland Pedestrian Master Plan)

Factor	Conditions	Points
<i>Sidewalk Continuity (= S)</i>	$S = \{[2/(swL + swR)] * 1000\} - 5$ <i>swL = % of sidewalk complete on “left” side of street</i> <i>swR = % of sidewalk complete on “right” side of street</i>	0 to 5
<i>Automobile-Pedestrian Crashes</i>	<i>6 crashes within 1000-ft radius over 5-year period</i>	5
	<i>4-6 crashes within 750-ft radius over 5-year period</i>	3
	<i>1-3 crashes within 500-ft radius over 5-year period</i>	2
<i>85th Percentile Traffic Speed</i>	≥ 52 MPH	5
	47 to 51 MPH	4
	43 to 46 MPH	3
	38 to 42 MPH	2
	33 to 37 MPH	1
<i>Traffic Volume (ADT)</i>	$\geq 25,000$	5
	17,500 to 24,999	4
	12,500 to 17,499	3
	7,500 to 12,499	2
	2,500 to 7,499	1
<i>Pavement Width</i>	> 90 ft	6
	> 80 to 90 ft	5
	> 70 to 80 ft	4
	> 60 to 70 ft	3
	> 50 to 60 ft	2
	> 40 to 50 ft	1
<i>Street Segment Length</i>	> 1,000 ft	5
	> 800 to 1,000 ft	4
	> 600 to 800 ft	3
	> 400 to 600 ft	2
	> 200 to 400 ft	1

4.2 Grade-Separated Pedestrian Crossings

Problem Statement. At selected locations, pedestrians must cross a wide, busy, high-speed arterial. Such crossings can be quite hazardous given the width of the roadway, the limited amount of time available for crossing, the lack of adequate gaps between passing vehicles, difficulties associated with identifying an appropriate time to cross, the possible lack of a pedestrian refuge, and, perhaps, the unavailability of an adequate crossing facility nearby. A number of pedestrians have been hit in making such crossings.

Literature Review. Moore and Older (1965) performed studies of pedestrian subways and bridges in London. Given a set of desired walking paths, the time required to cross a road using a subway or bridge was compared to the time required to cross the road at grade. The ratio of these two times was designated as R . The authors found that nearly 100% of the pedestrians used the subway if R was less than or equal to one – that is, if the travel time was equal to or less than the at-grade travel time. To reach nearly 100% usage of a bridge, R needed to be less than or equal to 0.75. The authors recommended that grade-separated crossings be placed along “main pedestrian routes.” To determine these routes, pedestrian origin-destination surveys are needed. Studies should also be done to determine R . If R is estimated to be greater than 0.75, then guardrails or other obstructions may be needed to prevent pedestrians from crossing at-grade.

In 1972, an ITE committee published a set of criteria for pedestrian overpasses. The following grade-separated crossing needs were suggested along highways having no access control:

- A strong desire for a pedestrian overcrossing, possibly being generated by a school board or citizen's group;
- The lack of a reasonable alternate route or mode for pedestrians needing to cross;
- The lack of a traffic signal, stop sign control, or grade-separated pedestrian overcrossing within 660 ft of the proposed location;
- A potential to prevent pedestrians from crossing at-grade;
- The practicality of constructing an overpass within existing physical conditions; and
- Traffic and pedestrian volumes that are greater than those that would warrant the installation of a pedestrian or school signal as indicated in the MUTCD.

To prioritize locations, a pedestrian overpass priority system was developed by the City of Seattle. For highways with full access control, a pedestrian overcrossing was recommended if a long circuitous route would otherwise be involved, there were a large number of pedestrians, school access needed to be provided, or pedestrian patterns included crossing the highway.

Richter and Fegan (1983) noted that, in general, the elderly and disabled prefer to use the longer but safer route offered by a grade-separated crossing. Hence, it is important that such facilities be serviceable to these pedestrians. Of principal concern are wheelchair and visually-impaired users. Among the pedestrian crossing design components that must be attended to include ramp gradients, ramp configurations, the slip resistance of walkway surfaces, surface textures, and the locations of landings and rest areas (along the way).

Zegeer and Zegeer (1988) described five types of grade-separated pedestrian facilities:

- Bridges and overpasses: Endpoints are located at grade level, and stairs or ramps lead up to the overpass; in other situations, the overpass is at grade and the road is depressed.
- Underpasses and tunnels: Stairs or ramps lead to an underground passage; in other situations, the passage is at grade and the road is elevated.
- Below-grade networks: Extensive underground walkways facilitate walking in an auto-free environment.
- Elevated walkways: These are sidewalks that are located above ground level.

- Skyways and skywalks: Enclosed walkways located one or more stories above ground level connect buildings, often at midblock.

The authors reported that a 1969 before-after study in Japan found that pedestrian-vehicle crashes were reduced by 85% per pedestrian structure. The evaluations were based on a zone 200 m in width on either side of a structure. Also, the authors determined that grade-separated pedestrian facilities were most beneficial where:

- The pedestrian crossing demand is moderate to high,
- A large number of young children must regularly cross a high-speed or high-volume road,
- High traffic volumes and high pedestrian crossing volumes combine with extreme hazards such as high speeds, wide streets, and poor sight distance, and
- One or more of the preceding conditions combine with a well-defined pedestrian origin and destination, such as a neighborhood-school pair or university-parking structure pair.

Grade-separated pedestrian facilities were considered to be minimally beneficially or even harmful:

- In high-crime areas (particularly for underpasses),
- When the facility is poorly designed or inconvenient for the elderly and disabled,
- Where no physical barriers have been constructed to control at-grade crossing activity, and
- Where the majority of pedestrians are unlikely to use the facility, such as near a high school.

A few of the advantages associated with grade-separated pedestrian facilities are the separation of pedestrians and vehicles, the improvement of vehicle circulation, and the reduction of delays to both pedestrians and vehicles. Overpasses are associated with low costs relative to underpasses and relatively easy maintenance. Underpasses are associated with weather protection, and can be shorter in length and less visually intrusive than overpasses. A few of the disadvantages of grade-separated facilities include a potential increase in pedestrian travel time, a lack of usage by pedestrians, visual intrusion and high clearance needs (for overpasses), and high maintenance and lighting needs (for underpasses).

Bowman et al. (1989) summarized a set of warrants for pedestrian separation. The authors presented the warrants in recognition that a strict series of requirements should not be used uniformly. It was recommended that pedestrian over and underpass installations be considered early in the planning of new developments. The suggested warrants were as follows:

1. Pedestrian volume > 300 during the highest continuous 4-hour period IF:
Vehicle speed > 45 MPH,
The proposed sites are in urban areas, AND
The proposed site is neither over nor under a freeway.
ELSE, pedestrian volume > 100 during the highest continuous 4-hour period.
2. Vehicle volume > 10,000 during the same 4-hour period OR ADT > 35,000 IF
Vehicle speed > 45 MPH AND
The proposed sites are in urban areas.
ELSE, vehicle volume > 7,500 in 4 hours OR ADT > 25,000
3. The proposed site is ≥ 600 feet from the nearest "safe" crossing.
4. A physical barrier to prevent at-grade crossings is desirable.

The authors recommended that artificial lighting should be provided 24 hours a day on underpasses and all night on overpasses. The elevation changes should be minimal to overpass and underpass users. Also, construction costs should not be excessive. A specific need for the crossing should either exist or be projected based on existing or proposed land uses adjoining the proposed site. Direct access should be

provided between the land use and the crossing. Funding for construction must be available prior to commitment to the project.

The Alaska DOT uses three warrants to determine the need for a grade-separated crossing: volume, gaps, and geometric conditions. Grade separation is warranted if any one of the three is met. The traffic volume warrant is based on a minimum average hourly volume (600) during 8 hours of an average day, combined with a minimum average hourly pedestrian volume (150). The minimum average hourly volume is reduced to 400 for official safe routes to school. The gaps warrant is met if the minimum value of the 85th percentile of approaching vehicle speeds exceeds 60 km per hour, a minimum crossing width of 12 meters is exceeded (excluding the shoulders and the median), a minimum average hourly volume (750) during the two heaviest pedestrian crossing hours is exceeded, and a minimum number of hourly gaps (60) for crossing during the peak pedestrian hours is not available. The gap adequacy is calculated using the following equation, which is from the Institute of Transportation Engineers' recommended practice entitled "A Program for School Crossing Protection" (ITE):

$$\text{Gap time (in seconds)} = (W/1.07) + 3 + 2(N-1), \text{ where}$$

W = curb to curb width of road (meters), and

N = number of rows of pedestrians.

The geometric conditions warrant is that "the available sight distance is less than the stopping sight distance required by the 85th percentile approach speed, and no other crossings are available for a distance of 150 meters from the location." Alternatively, "a full freeway intersects a pedestrian way where no vehicular structure is to be built, and no other pedestrian crossing of the freeway is available within 150 meters."

Louisiana's warrants cover the installation of both over and underpasses. The warrants apply to both pedestrians and bicyclists, and they are based entirely on volumes. On freeways, the minimum volumes are 100 pedestrians or bicyclists during any 4-hour period, 7,500 vehicles during the same 4-hour period, and an annual average daily traffic volume (AADT) of 25,000. On arterials, the minimum volumes are 300 pedestrians or bicyclists during any 4-hour period, 10,000 vehicles during the same 4-hour period, and an AADT of 35,000. The higher vehicular speeds on freeways are associated with their lower volume warrants. The criteria require that both the pedestrian-bicycle and vehicle volume warrants be met. Exceptions are made when any one count greatly exceeds the threshold, or when a large percentage of the pedestrians or bicyclists are schoolchildren. If a nearby, "attractive" crossing opportunity is available, then the warrant is negated.

Pedestrian bridges are constructed in Michigan based on a number of location and demographic, rather than numerical factors. A concise summary of Michigan's guidelines, in place since the mid-1970s, is as follows:

Limited-access facilities

- In rural areas, pedestrian bridges are built to provide access to elementary schools where other practical means of access are not available.
- In urban areas, pedestrian bridges are constructed where "reasonable movements" by the public would otherwise be denied.

Unlimited-access facilities

- In the event of a traffic pattern change, a pedestrian bridge is built if elementary school crossing hazards are increased. Local school officials make the request.

- Where there is no significant pattern change, local authorities may request a permit to build a pedestrian bridge.

Portland, Oregon. Use a grade-separated crossing where it is not possible to provide an at-grade facility, such as at a freeway, major highway, rail yard, or waterway.

Florida. A grade-separated crossing is needed when a highway features six or more lanes. An overpass or underpass may also be needed in the following situations: two activity centers are separated by a roadway; two segments of a multimodal (pedestrians and bicycles) trail need to be connected. The criteria and warrants developed by Axler (1984) are preferred. The warrants are based on a combination of pedestrian volumes, traffic volumes, motor vehicle speeds, and the distance from the nearest “safe” crossing. A list of over 30 factors has been developed for evaluating the benefits of separating pedestrians and vehicles (NCHRP Report Nos. 189 and 240). These factors should be considered prior to making a decision regarding grade separation. Florida’s handbook recommends that grade-separated facilities be incorporated into the early stages of planning new developments since such facilities are associated with high costs. The handbook’s suggestions are as follows:

Overpasses

- A very high volume of both motorized traffic and pedestrian activity should exist. One measure of activity is gaps in the traffic stream. If gaps are effectively absent, then the warrant is met.
- Roads featuring high speeds, many lanes, and limited gaps are candidates for grade-separated facilities. The need for grade separation at such high-risk crossing conditions may be most prevalent near schools or other activity centers such as sporting or entertainment complexes.
- Two activity centers may be connected by a grade-separated pedestrian facility. Examples might be an athletic field that is separated from a school, or an auxiliary campus that is separated from the main campus. The connection should be designed to minimize the lengths of stairs and ramps.
- Wide bridges (3.1 m or 10 ft or more) are recommended. The facility should be open and well-lit.
- Locating commercial kiosks or other activity centers at or near an overpass is encouraged to curtail crime and other unwanted activity.
- An overpass is recommended to provide continuity along pedestrian and bicycle trails. For access to the trail or bridge structure, a terraced climb is suggested.
- All overpasses must meet Americans with Disabilities Act (ADA) standards.

Underpasses

- Tunnels must be well-lit. A large skylight in the center of tunnel, placed in the median of the overhead road, is one approach. Luminaries above the skylight can be used for night lighting.
- Tunnels should have vandal-resistant walls. Artwork or glazing may promote the resistance of vandalism.
- Tunnels should have a split-grade design, such that pedestrians can see the horizon at the far side of the facility. To achieve this effect, the roadway needs to be raised a bit; then, the tunnel is depressed by half of the total elevation change.
- It is essential to locate robust commercial and entertainment activity near tunnels to ensure the safety and security of the users.
- Tunnels must meet ADA standards.
- Tunnels should have good drainage, and drainage grates must be pedestrian friendly.
- Video monitors may be installed to enhance the security of pedestrians.

New Jersey. Candidate locations for grade separation include areas where there are attractors – large schools, shopping centers, recreational areas, parking garages, other activity centers – that are separated by arterials from residential “generators.” The warrants for over- and underpasses are as follows:

Facility	Pedestrian Volume	Motor Vehicle Volume	
	4-Hour Total	4-Hour Total (same 4 hours)	AADT
Freeway	100	7,500	25,000
Arterial	300	10,000	35,000

Design and construction specifications for over- and underpasses include the provision of artificial lighting (at least 10 fc or 108 lux in underpasses) and accessibility by ramps. Where motor vehicle volumes substantially exceed the warrants, or where there is restricted sight distance, consideration should be given to erecting a physical barrier to prevent at-grade crossings by pedestrians. Design, however, should be oriented toward making the grade-separated crossing as attractive as possible to the pedestrian, rather than toward the prohibition of at-grade crossings.

A median of width 3 m (10 ft) or more may be an acceptable crossing alternative to grade separation. Additional opportunities for grade-separated pedestrian crossings include integration with stream or railroad crossing structures.

Washington. A grade-separated crossing is recommended when there is a moderate to high pedestrian demand to cross a freeway or expressway. A grade-separated crossing is also recommended when a large number of young children must cross a high-speed or high-volume road. Streets with high numbers of motor vehicles and pedestrians, particularly where the crossing is wide and there is poor sight distance, are candidates for grade-separated crossings. Finally, a well-defined pedestrian origin-destination pair, in combination with the preceding street widths, speeds and volume levels, is a candidate for a grade-separated crossing.

Discussion. The criteria for grade-separated pedestrian crossings have been well-developed and extensively addressed in the literature and agency policies. There is no common set of standards for grade-separated crossings. In Louisiana, the need for a pedestrian bridge is based on the 4-hour pedestrian or bicycle volume, the 4-hour traffic volume, the AADT, and the functional classification of the road. In Michigan, the needs are determined based on the proximity of an elementary school, public access requirements, and local concerns. Alaska’s guidelines are quite data intensive, involving the potential need for pedestrian crossing volumes, the spot speeds of approaching vehicles, and analysis of the gaps between vehicles. Michigan’s policy represents the opposite extreme, with no numerical requirements, and needs based entirely on engineering judgment and local concerns. Louisiana’s approach, perhaps, represents the middle ground, with fairly simple data requirements, and a consideration for both pedestrians and bicycles. Further, Louisiana’s policy applies to both over and underpasses. Given the variety of policies, it is clear that further research into the appropriate parameters for a grade-separated pedestrian crossing is needed. Until such research is conducted, it is possible to consolidate the various criteria, and integrate them into UDOT’s existing grade-separated pedestrian crossing policy.

It is interesting to observe that none of the grade-separated crossing criteria incorporate pedestrian-vehicle collisions. It may be possible to substitute pedestrian-vehicle crashes for pedestrian volumes, since crashes might be a “proxy” for a walking demand. Further research is needed on pedestrian-vehicle crash criteria, particularly since pedestrian-related crashes will occur fairly infrequently at a given site. Contrarily, a number of grade-separated crossing structures have been built in response to pedestrian-vehicle incidents. This is a reactive approach that should probably be avoided. That is, criteria should indicate the need for a grade-separate crossing before a regrettable incident occurs.

A number of grade-separated pedestrian crossing facilities exist in Utah. The research team did not attempt to compile an inventory of these. Observations indicated, though, that such facilities were

commonly located adjacent schools. New Jersey's guidelines refer to the option of using a raised median instead of a grade-separated crossing. As noted earlier in this report, the criteria for pedestrian refuges are based entirely on crossing distances and pedestrian volumes; there is no consideration for traffic volumes, motor vehicle speeds, or other factors. If pedestrian refuges are to be considered as an alternative to grade-separated crossings, then a more comprehensive set of criteria need to be developed. This would enable an effectiveness analysis of the tradeoffs.

Example Guidelines. *The following are some example grade-separated pedestrian crossing criteria. These might be considered for integration into UDOT's existing grade-separated pedestrian crossings policy. Install a grade-separated crossing when the following conditions are met:*

Quantitative Criteria

- *There is no alternative crossing within 150 m of the candidate location.*
- *The existing or anticipated pedestrian crossing volume exceeds:
100 in 4 hours IF the crossing barrier is a freeway, river, canal, railroad, or other impedance, OR
300 in 4 hours IF the crossing barrier is a surface street*
- *For crossings of surface streets:
The 85th percentile motor vehicle speed exceeds 40 MPH AND
The ADT exceeds 35,000 AND
There is no raised median or pedestrian refuge AND
More than four lanes must be crossed, including turning lanes*
- *IF pedestrian volume data are not available OR in lieu of pedestrian volumes, consider a grade-separated crossing IF, along a 300 m road segment with no crossing facilities, there have been three or more pedestrian-vehicle crashes in ten years, two or more pedestrian-vehicle crashes in five years, OR two more pedestrian-vehicle crashes in three years.*

Qualitative Criteria

- *The crossing would serve a well-defined origin-destination pair, such as a school and a residential area, a parking facility and a shopping center, a neighborhood and a park, a transit stop and a campus, etc., AND*
- *There is a need to prevent or offer an alternative to at-grade crossings OR*
- *There are natural or man-made barriers to pedestrian crossings OR*
- *Alternative crossing routes are long and circuitous OR*
- *There is community support for a grade-separated crossing.*

Additional Considerations

If the crossing would serve a school, be heavily used by children, or be heavily used by elderly or disabled pedestrians, then the values of the quantitative criteria can be reduced. If at-grade crossings are perceived to be particularly hazardous at the candidate location, then barriers to prohibit crossings – fencing, walls, shrubbery – may need to be established. The purpose of the prohibitions would be to encourage usage of the grade-separated crossing. In addition to high speeds, heavy traffic volumes, and a wide crossing distance, other hazards would include poor sight distances and a lack of gaps between oncoming motor vehicles. To minimize costs or to provide alternative routing, other structures, such as stream crossings and railroad bridges, might be examined for their ability to accommodate pedestrians. These proposed guidelines do not include, at this point, any factors that could be used to compare over- and underpasses.

The research team identified the following sites that might be considered for a grade-separated pedestrian crossing. Pedestrian-vehicle crashes, rather than pedestrian volumes, were among the inputs in selecting the sites.

Table 6. Locations Meeting the Example Criteria for Grade-Separated Pedestrian Crossings

City or CDP	Location	AADT	Lanes	Speed	Nearest Xing	Land Uses
<i>Millcreek</i>	<i>700 East at Rowley Dr (4348 South)</i>	<i>40,170</i>	<i>8</i>	<i>50</i>	<i>4500 South</i>	<i>Residential</i>
<i>Murray</i>	<i>State Street at 5770 South</i>	<i>28,920</i>	<i>7</i>	<i>45</i>	<i>5600 South</i>	<i>Shopping</i>
<i>Ogden</i>	<i>Wall Avenue at 27th Street</i>	<i>28,385</i>	<i>5</i>	<i>40</i>	<i>25th St; 29th St</i>	<i>Business</i>
<i>Salt Lake City</i>	<i>700 East at Simpson Avenue</i>	<i>39,770</i>	<i>8</i>	<i>40</i>	<i>2100 South</i>	<i>Business</i>
<i>Salt Lake City</i>	<i>North Temple east of 1950 West</i>	<i>34,321</i>	<i>6</i>	<i>50</i>	<i>Redwood Road</i>	<i>Business</i>

NOTES: CDP = U.S. census designated place (unincorporated area); AADT = year 2002; Lanes = number of through and turning lanes. Speed = speed limit (MPH). None of these locations featured a marked crossing or raised median as of 2003 and 2004 field visits. Three or more pedestrian-vehicle crashes occurred at each of these locations between 1992 and 2001. Wall Avenue (Ogden) was under construction as of the research team's visit.

CHAPTER 5.0 Pedestrian-Turning Vehicle Conflicts

5.1 Conflicts Between Crossing Pedestrians and Right-Turning Vehicles

Problem Statement. Conflicts between right-turning vehicles and crossing pedestrians are fairly common. One problem is that the pedestrian must look to his or her left and behind to observe an oncoming, turning vehicle. At the same time, the driver will commonly be looking to his or her left, failing to notice a pedestrian who is crossing on the vehicle's right side. Conflicts can also occur when the pedestrian is approaching a vehicle from the driver's left. Many drivers fail to notice oncoming pedestrians, concentrating instead on oncoming vehicles. The latter conflict is, perhaps, most prone to occur at a signalized intersection that allows right turns on red. In all cases, a pedestrian who has a green signal, thereby having clearance to cross, may not exercise due vigilance in his or her looking behavior. Similarly, a driver who is intent on making a right turn may be most concerned with oncoming vehicles on the cross street, and only secondarily concerned with crossing pedestrians.

Literature Review. Zador (1984) found that pedestrian-vehicle crashes increased by about 60% at signalized intersections following the introduction of right turn on red. By placing a TURNING TRAFFIC MUST YIELD TO PEDESTRIANS sign (61 x 76 cm, black lettering on white background) on the corner opposite a right-turn maneuver, Abdulsattar et al. (1996) found that pedestrian-vehicle conflicts were reduced by 15 to 30%. The authors evaluated 2,905 "before" and 2,565 "after" observations at six intersections in Omaha, Nebraska. Retting et al. (1996) placed the responsibility for reducing conflicts between pedestrians and turning vehicles on the pedestrians. Their approach was to introduce a combination of a LOOK FOR TURNING VEHICLES sign and a WATCH TURNING VEHICLES pavement marking at intersection corners. The authors observed that the number of conflicts per 100 pedestrians reduced from 2.5 to 3.1 (with no improvements) to 0 to 1.2 (with improvements). The findings were based on observations of about 1,200 pedestrians at three intersections in Clearwater, Florida and Dartmouth, Nova Scotia.

Animated eyes in pedestrian signal heads were evaluated by Van Houten et al. (1999). The pedestrian head display was enhanced by two eyes in which the eyeballs wandered from left to right. The purpose of the wandering eyes was simply to remind pedestrians to look for turning vehicles. The authors acknowledged that similar reminders on signs and in pavement markings would have the same effect; it was argued, however, that the incorporation of the eyes into existing pedestrian signals would be more economical than broad implementation of new signs and markings. In an evaluation of two intersections in Clearwater, Florida, it was found that the portion of pedestrians *not* looking for turning vehicles was between 26 and 32%. With the animated eyes in place, the portion not looking decreased to 5 to 10%. A total of about 3,600 pedestrians were observed under various permutations of the "eyes" display.

Portland, Oregon. Right-turn slip lanes are *not* recommended in areas of high pedestrian demand.

Florida. Evaluate a right-turn-on-red prohibition on a case-by-case basis. Use a NO TURN ON RED WHEN PEDESTRIAN IS PRESENT sign as an alternative to absolute prohibition. Case studies should consider the usage of the crossing by children (unpredictable behavior) and the elderly and disabled (slow perception-identification-emotion-volition, or PIEV times and crossing speeds). Consider designing compact intersections with small turning radii, thereby forcing turning speeds to be slow – 24 KPH (15 MPH) or slower is recommended. If a right-turn-on-red prohibition is considered, also examine the potential increase in right-turn-on-green conflicts. If the intersection has a right-turn slip lane, place the crosswalk as far upstream as possible to increase the visibility of pedestrians to the right-turning driver. A warrant for a crosswalk and porkchop refuge is when the product of crossing pedestrians and right-turning vehicles is 800 or more. Use yield control for the right-turn slip lane. Avoid using double- or triple-turn lanes under signal control.

New Jersey. Prohibit right-turn-on-red at intersections where pedestrian volumes are significant and where field studies suggest this treatment. Right turn slip lanes may be warranted wherever turning volumes and traffic types warrant. *Double* right turn lanes, however, are very dangerous for pedestrians because a vehicle in the inner lane can block the vision of the driver in the outer lane.

Washington. Compact intersections with small turning radii that force slow turning speeds can be designed. Such designs may not be feasible where large trucks and buses turn frequently. A right-turn-on-red prohibition can be considered. Where right-turn slip lanes are used, place crosswalks as far upstream as possible and provide highly visible pavement markings. Shorten the crossing distance with curb extensions or bulbouts.

Discussion. A number of interventions have been proposed or tested for the purpose of reducing conflicts between pedestrians and right-turning vehicles. These include signing directed at drivers, signing and pavement markings directed at pedestrians, pedestrian signal enhancements, right turn lane and curb radius design constraints, and right turn prohibitions. Each of these interventions has been successful in reducing pedestrian-vehicle conflicts. The most economical measures, perhaps, involve low-cost signing and markings. Salt Lake City was using a TURNING VEHICLES YIELD TO PEDESTRIANS sign, separately and in combination with LOOK messages directed at pedestrians. The city's installation criteria for the sign consider the location's conflict history. There are no reports on the impacts of combined signing and markings for drivers *and* pedestrians. Each strategy has produced successful results individually. It is likely that the combination of signing and markings for drivers and pedestrians would work toward producing the desirable effects.

The research team did not examine pedestrian-vehicle crashes according to the driver action prior to the incident. Such an effort might have identified pedestrian-vehicle crashes resulting from conflicts with right-turning vehicles. It would be useful to pursue this as a means of identifying locations at which right turn-related interventions are needed.

Another safety intervention at signalized intersections is a "head start" for pedestrians, also known as a leading pedestrian interval (LPI). King (1999) reported on New York City's extensive experience with LPIs, some of which had been in place for about 20 years. The LPIs ranged in duration from 5 to 19 sec, with the longer intervals associated with greater pedestrian volumes. A total of 26 intersections with LPIs were compared to similar intersections not having LPIs. Pedestrian-vehicle crash data were collected over a 10-year period. The author estimated that the LPIs could be attributed with a 12% reduction in pedestrian-vehicle crashes. It is likely that the LPIs also had a substantial impact on pedestrian-vehicle conflicts; these were not quantified, however. The author did not discuss criteria used to select intersections for LPIs, other than that they had "heavy pedestrian and vehicle volumes." Given that New York City features high pedestrian volumes at many locations, compared with other cities, a shorter LPI of 3 to 5 sec might be appropriate in general. The minimum LPI might indeed be 3 to 5 sec, given the need to accommodate pedestrian startup times, which do not depend on the number of pedestrians crossing.

Example Guidelines. *Consider implementing the following at each corner of each intersection warranting right turn-related interventions:*

- *Install a TURNING VEHICLES YIELD TO PEDESTRIANS or TURNING TRAFFIC MUST YIELD TO PEDESTRIANS sign in advance of a pedestrian crossing. Additional study may be needed to determine the optimal location for the sign.*
- *As discussed under "Guidance for Pedestrians at Crossings" (section 2.5), paint LOOK on the pavement at the two extreme ends of each crosswalk.*
- *Install a WATCH FOR TURNING VEHICLES (or LOOK FOR TURNING VEHICLES) sign at the portals of each pedestrian crossing.*

Further study is needed to determine when right turn-related interventions are “warranted.” The warrants might be based on a history of crashes between pedestrians and right-turning vehicles, a history of conflicts between pedestrians and right-turning vehicles, heavy pedestrian activity, or a combination of all of these.

At locations having or planned for right-turn slip lanes, such as busy intersections and freeway interchanges, consider providing just one turning lane (as opposed to providing two or three lanes). Place the crosswalk well upstream of the apex of the turn to increase the visibility of crossing pedestrians. Provide a channelizing “porkchop” island, and let it serve as a refuge for pedestrians. Use signing as proposed above, but let the WATCH FOR TURNING VEHICLES sign be a supplement to a USE CROSSWALK sign (R9-3b). These two signs could be installed on the same post.

At particularly busy (pedestrians and vehicles) signalized intersections, consider using a leading pedestrian interval (LPI). The LPI should be between 3 and 5 sec; longer LPIs may be needed at locations with very heavy pedestrian volumes. King (1999) noted that the LPI need not have a measurable effect on motor vehicle delays or traffic signal cycle lengths. Further study is needed to develop warrants for LPIs.

5.2 Conflicts Between Crossing Pedestrians and Left-Turning Vehicles

Problem Statement. Conflicts between left-turning vehicles and crossing pedestrians are fairly common. The problem is most pronounced when left turns are “permitted” at an intersection; that is, the left-turning drivers must wait for a gap in oncoming traffic. Since the driver must concentrate on finding an adequate gap, there may be a tendency to ignore the need for a gap between crossing pedestrians. Further, a driver may fail to be attentive to a pedestrian who has started his or her crossing maneuver from the corner immediately to the driver’s left.

Literature Review. Habib (1980) found that pedestrians were twice as likely to be hit by left-turning motor vehicles than by right-turning vehicles at intersections. The author recommended that the left-turn signal head be placed on the far-side corner to the left of the driver, rather than immediately over the left turn lane (or, perhaps, in addition to the overhead light). The alternative signal head placement would encourage eye contact between the driver and crossing pedestrians. By placing a TURNING TRAFFIC MUST YIELD TO PEDESTRIANS sign on the corner facing a left-turn maneuver, Abdulsattar et al. (1996) found that pedestrian-vehicle conflicts were reduced by 20 to 65%. The authors evaluated 1,273 “before” and 1,039 “after” observations at six intersections in Omaha, Nebraska.

Portland, Oregon. This agency’s guidelines do not address this issue directly.

Florida. Use a separate left-turn phase for motorists, during which pedestrians are prohibited from crossing. Consider restricting left turns in downtowns and commercial zones.

New Jersey. Prohibit left turns in downtowns or commercial zones, or where high concentrations of elderly pedestrians are present, if analysis indicates that conflicts between pedestrians and turning vehicles are creating safety or capacity problems. In some situations, protective left turn signal phases can mitigate these conflicts.

Washington. Use a separate left-turn phase in conjunction with a pedestrian signal. Alternatively, restrict left turns at “downtown” intersections and along streets with a high level of commercial activity during certain hours when there are high concentrations of pedestrians. Shorten the crossing distance with curb extensions or bulbouts. Avoid dual left turns at intersections that are used by pedestrians.

Discussion. Four interventions are discussed in the literature and by agencies: signing, left turn signal head placement, left turn phasing, and left turn prohibitions. The least costly approach, which has been successful in reducing conflicts between pedestrians and left-turning vehicles, is to install a sign, facing left-turning drivers, reminding them to yield to pedestrians. It is evident that the *positioning* of such a sign is critical to its success. Finding the ideal position for the sign may require some experimentation, and may vary by location.

Protective left turn phasing would eliminate the need for other interventions. There are no warrants for left turn signal phasing in the MUTCD, however. Many state and local agencies have developed their own left turn signal warrants. Caltrans, for example, warrants left turn phasing based on the history of crashes, left turn delays, left turn and conflicting through volumes, sight distance, and heavy turning movements by large vehicles. The Caltrans warrants do not consider pedestrians, though; it is unknown how many, if any, agencies consider pedestrian volumes in their left turn signal warrants. Also, it is common for left turn signal warrants to *not* distinguish between the *type* of phasing needed. Further research is needed on left turn signal warrants and on criteria for left turn phasing schemes. It is not known if there are plans for the development of a MUTCD left turn signal warrant.

The preceding discussion on LPIs is applicable to the left turn conflicts issue. King (2000) discussed applications of the LPI to all types of motor vehicle turning movements.

Example Guidelines. *Consider implementing the following at each corner of each intersection warranting left turn-related interventions:*

- *Install a TURNING VEHICLES YIELD TO PEDESTRIANS or TURNING TRAFFIC MUST YIELD TO PEDESTRIANS sign within the cone of vision of left-turning drivers. Further study is needed to determine the optimal location for this sign; the optimal location may vary from site to site.*
- *If not already done as part of right turn-related interventions or pedestrian crossing enhancements, paint LOOK on the pavement at the two extreme ends of each crosswalk.*
- *As above, if not already done, install a WATCH FOR TURNING VEHICLES (or LOOK FOR TURNING VEHICLES) sign at the portals of each pedestrian crossing.*

Further study is needed to determine when left turn-related interventions are “warranted.” The warrants might be based on a history of crashes between pedestrians and left-turning vehicles, a history of conflicts between pedestrians and left-turning vehicles, heavy pedestrian activity, or a combination of all of these.

In addition to the above proposals, work toward the development of a left turn signal warrant that incorporates pedestrian volumes, and that distinguishes between different types of left turn phasing. Protective left turn phasing would eliminate the need for other left turn-related interventions. Finally, in a similar vein as the discussion on pedestrian conflicts with right-turning vehicles, consider installing an LPI at particularly busy locations. An effective LPI duration would enable the pedestrian to clear the path of a left-turning vehicle. At multilane crossings, this would require a longer LPI than would be needed to for a pedestrian to clear a right-turning vehicle’s path.

CHAPTER 6.0 Measures and Strategies Targeted at Drivers

6.1 Placement of Warnings to Drivers

Problem Statement. The driver's statement on a number of Police Accident Reports was effectively "I did not see the pedestrian." The supposition is that warning devices directed at the driver, placed upstream of the crossing, may have improved the driver's attentiveness to pedestrians. (It is recognized, though, that a number of collisions occurred when the pedestrian did not use a crosswalk).

Literature Review. Burritt et al. (1990) and Sparks and Cynecki (1990) suggested that flashing beacons at pedestrian crossings were not effective in reducing the speeds of motor vehicles. These authors' evaluations did not, however, ascertain the impacts of the flashers on pedestrian safety. Harrell (1994) found that the presence of a warning sign located 48 m upstream of a crosswalk had no effect on motorists' yielding during the daytime (the study did not cover nighttime activities). Contrarily, Van Houten and Malenfant (1992) found that the introduction of a STOP HERE FOR PEDESTRIANS 50 ft upstream of a crosswalk increased the distance from which motorists began to brake for pedestrians, and reduced the number of pedestrian-vehicle conflicts. A flashing light located at the crosswalk was found to have no impact on driver yielding behavior in the presence of the sign (that is, drivers yielded whether or not the light was activated). The authors also found that an advance stop line led to further improvements in yielding and conflicts. A similar finding was obtained by Van Houten et al. (2001), who evaluated advance yield markings combined with a sign prompting motorists to yield to pedestrians. Markings and a sign placed 10 m in advance of a crosswalk was found to increase the upstream distance at which drivers stopped and reduce the number of pedestrian-vehicle conflicts. Similar results were obtained when the markings and sign were placed 15 to 25 m upstream of the crosswalk. Lalani (2001) confirmed these findings, noting that low-cost signing and striping techniques at and near crosswalks were effective. Van Houten and Malenfant (2001) also found that animated LED "eyes" positioned at parking garage exits improved the yielding-to-pedestrians behavior of drivers. The animated eyes displays were not tested on open roadways, though.

Yet another enhancement to marked crosswalks is a series of advanced pavement markings on the approach to the crossing. Kanner et al. (2003) reported on an application of advance yield markings in Nova Scotia. The markings consisted of a transverse series of solid white triangles, each 40 cm at the base and 60 cm in length, painted from 7 to 15 m in advance of a crosswalk. The advance yield markings were installed in combination with in-street pedestrian yield signs. At 24 urban and rural sites, the portion of drivers stopping 6 m in advance of the crosswalk increased from 13% before to 54% after the signs and markings were installed; drivers stopping 3 m in advance of the crosswalk increased from 37% before to 83% after. These results suggested that the markings and signs in combination were more effective than either the markings or the signs alone.

Portland, Oregon. This subject is not discussed in the agency's guidelines.

Florida. Install warning signs in advance of midblock crosswalks. A 0.9 m x 0.9 m size (larger than the MUTCD's 0.75 m x 0.75 m standard) is recommended for high-speed or wide arterials. At stop sign-controlled intersections, the stop sign should be placed in advance (1.2 m or 4 ft) of the crosswalk. At midblock crossings, the stop line should be placed 12.2 m (40 ft) from the crosswalk. Use pavement word and symbol markings (SCHOOL XING; PED XING) on high-speed arterials, particularly along horizontal or vertical curves.

New Jersey. This subject is not discussed in the agency's guidelines.

Washington. Flashing beacons are most effective if they operate only during times when there is a clear need to alert the motorist, such as when pedestrians are present.

Discussion. As of October 2002, Salt Lake City had installed advance crosswalk “5-bar triangle” markings at four locations, and there were plans to install 25 others. The 5-bar markings were designed by the City staff and are different from those used in Nova Scotia (as discussed earlier). There have not yet been any reports on the effectiveness of the markings. The positioning of these markings at a distance greater than 15 m upstream of the crossing is in conflict with the recommendation for stop and yield lines in the MUTCD; the MUTCD limitations are 15 m upstream for midblock locations and 9 m for intersection crossings.

Further study of upstream advance warning pavement marking distances is suggested. The literature indicates that the location at which an advance warning of a pedestrian crossing is placed is critical to the warning’s effectiveness. Warnings placed well in advance of a pedestrian crossing – greater than 25 m – have not had desirable impacts on motorist speeds and yielding behavior. Warnings positioned from 7 to 25 m in advance of a crossing, however, have been observed to reduce motorist speeds and increase the percent of drivers who yield to pedestrians. Advance stop lines and supplementary signing have contributed to the effectiveness of pavement markings. Flashers and beacons have been observed to be effective for a period following installation, but then “lose their impact” as drivers “get used to them.” Their effectiveness can be enhanced if they are activated only when a pedestrian is crossing. It is possible, though, that lower-cost markings and signing can have an impact that is similar to that of warning lights.

Example Guidelines. *Install advance warning pavement markings from 7 to 25 m upstream of marked crossings at uncontrolled locations. The triangular pattern used in Nova Scotia has been very effective; a variation on this pattern has been developed and implemented in Salt Lake City. Further study is needed, though, on the effectiveness of various marking patterns. Markings placed between 7 and 15 m upstream of a crosswalk have been effective; further research is needed to determine ideal spacing distances from marked crossings as a function of approach speed, available sight distance, and other factors. Cluttering the pavement with multiple markings should be avoided, as this may lead to driver confusion. In each case, supplement the advance warning pavement markings with signs that prompt drivers to yield to pedestrians; standard signage, such as W11-2 with W16-7p, preceded upstream by a second W11-2, should be sufficient.*

6.2 Effectiveness of Signing Only at a Crossing

Problem Statement. A select few pedestrian crossings feature signs but no markings. One crossing visited by the research team, for example, featured a pedestrian crossing sign (W11-2), but no crosswalk. The notion is that crosswalk markings can lull a pedestrian into a “false sense of security,” as suggested by Herms (1972). Pedestrians may exercise greater vigilance in crossing a road when there are no markings. The concern is that signs alone are not as effective as a combination of signs and markings.

Literature Review. Zegeer et al. (2001), through a comparison of 1,000 marked with 1,000 unmarked crossings at uncontrolled locations, found that crosswalks on two-lane roads had neither a positive nor a negative effect on pedestrian safety. Crosswalks on roads with four or more lanes were associated with higher numbers of pedestrian-vehicle incidents than unmarked crossings of wide roads. The authors’ study did not investigate signalized or stop sign controlled crossings. Crosswalks at uncontrolled locations on wide roads (four or more lanes) *must* be supplemented by other devices (signs, markings, etc.) to improve their effectiveness.

Portland, Oregon. This subject is not discussed in the agency’s guidelines.

Florida. This subject is not discussed in the agency’s guidelines.

New Jersey. This subject is not discussed in the agency's guidelines.

Washington. This subject is not discussed in the agency's guidelines.

Discussion. The issue of providing signage but no marked crossing is associated with the Herms (1972) study, in which crosswalks were associated with an increased risk of pedestrian injury. One outcome of this study is the concept of enhancing the safety of the pedestrian by adequately warning drivers of a crossing, but leaving the crossing unmarked. The research team did not identify an agency with a specific policy to provide pedestrian crossing signs at unmarked crossings. Some agencies referred to the need to install a pedestrian crossing sign at locations at which drivers "do not expect to see" crossing pedestrians.

Unmarked crossings are legislated as explained in the Utah Administrative Code (see section 1.2). In general, a pedestrian crossing exists on all legs of any intersection, even when a sidewalk is absent, unless the crossing is prohibited by signing. Warning signs for drivers are not consistently placed at or upstream of unmarked crossings, though. The MUTCD refers to the use of nonvehicular warning signs, including the Pedestrian Crossing sign (W11-2), "to alert road users in advance of locations where unexpected entries into the roadway or shared use of the roadway by pedestrians, animals, and other crossing activities might occur." Also, a nonvehicular warning sign may be supplemented with a plaque such as NEXT XX MILES "to provide advance notice to road users of crossing activity."

Example Guidelines. *The research team was unable to identify any extensive discussion of this issue in the literature or agency policies. Based on the limited amount of information available, two strategies are possible. One strategy would be to provide advance warning to motorists of a stretch of road featuring general pedestrian activity – not necessarily crossing activity, and not necessarily in association with a downstream marked crossing – by installing a Pedestrian Crossing sign (W11-2) along with a supplemental plaque NEXT XX MILES. Another strategy, to be used at legal, unmarked locations where pedestrians are known to cross, would be to supplement the Pedestrian Crossing sign with a diagonal downward pointing arrow sign (W16-7p). Further review of the literature and agency policies regarding the signing of unmarked crossings is needed.*

6.3 Motorist Stopping Behavior, Policy and Law

Problem Statement. A number of pedestrian-vehicle collisions have occurred when a pedestrian, obstructed by or exiting a stopped vehicle, was struck by a passing vehicle. When a pedestrian is occluded by a stopped vehicle *but has the right of way*, a passing motorist is obligated to be attentive and stop. When a pedestrian is occluded but does not have the right of way, the pedestrian must be attentive to oncoming vehicles, but the oncoming motorist must "respect" the stopped vehicle and be prepared to stop. Similarly, a pedestrian who is exiting a stopped vehicle must be attentive to passing motorists; this is of particular concern if the vehicle is disabled and is, perhaps, stopped in an awkward location. But, as in the preceding situation, the passing motorist must be attentive to the disabled vehicle, perhaps giving the vehicle a "wide berth."

Literature Review. Various jurisdictions have special regulations for various situations in which motorists must stop. In Missouri, for example, motorists must stop 8 ft or more from the rear of a stopped streetcar that is headed in the same direction, and must remain stopped as long as the streetcar is taking on or discharging passengers. Motorists are also required to stop at a crosswalk at which another vehicle has stopped. Many jurisdictions require motorists to stop in the presence of a stopped school bus; severe penalties are often associated with violating this requirement.

Portland, Oregon. This subject is not discussed in the agency's guidelines.

Florida. This subject is not discussed in the agency's guidelines.

New Jersey. This subject is not discussed in the agency's guidelines.

Washington. This subject is not discussed in the agency's guidelines.

Discussion. In Utah, as in many other jurisdictions, motorists must stop when a school bus is displaying alternating flashing red signals. This requirement is relaxed if the bus is traveling in the opposite direction along a divided or multilane highway, or is in an intersection that is controlled by a signal or officer. Motorists are also required to stop at a crosswalk if one or more other motor vehicles are stopped at the crossing. New legislation requires motorists to slow down and change lanes if a Utah Highway Patrol or other emergency vehicle is stopped on the shoulder of a freeway.

Example Guidelines. *There are no specific guidelines to address the motorist stopping behavior issue at this time. Utah's motor vehicle laws are specific on driver responsibilities in the presence of stopped school buses, emergency and Utah Highway Patrol vehicles, and motor vehicles at crosswalks. Utah's laws do not cover disabled vehicles, though. Also, it may be unclear to motorists as to their obligations when a motor vehicle is stopped at an intersection approach having a green signal. Wording in Utah's Administrative Code might be developed to clarify this issue. Driver education should emphasize the need to be attentive when a vehicle has stopped at a location along a roadway other than the shoulder. Drivers should be aware of the possibility of crossing pedestrians or exiting motor vehicle occupants in these situations.*

6.4 Driver Penalties Following Pedestrian-Vehicle Collisions

Problem Statement. In their review of 34 Police Accident Reports (PARs) on fatal pedestrian-vehicle crashes, the research team found the following common themes when the driver was not intoxicated:

- The driver did not see the pedestrian.
- The pedestrian's behavior was errant, such as crossing away from an intersection, allegedly darting out, or crossing against a traffic signal.
- The driver was cited for a traffic violation such as speeding, or was not cited at all.

The issue is that driver penalties are not commensurate with the medical and financial impacts of pedestrian injuries following collision with a motor vehicle. Thus, there is little enforcement-related incentive for drivers to change their behavior. Also, the tendency to hold the pedestrian at fault ignores the possibility that adequate pedestrian facilities were nonexistent adjacent the crash site.

Literature Review. Marosi and Herndon (1999) reported that pedestrians in California were often placed at fault in the event of being struck by a motor vehicle. The authors admitted that California law was holding motorists less responsible than in many other States for crashes involving pedestrians. A similar tendency to "blame the pedestrian," however, was observed in this research's review of Utah PARs. Citations for pedestrian-vehicle incidents in California typically held the driver responsible for the associated motor vehicle infraction, but not for hitting the pedestrian. If a driver hit a pedestrian while speeding or because of ignorance of a stop sign, for example, then the driver was penalized for the infraction with no additional penalties for hitting someone. As of 1999, the maximum fine in California for hitting a pedestrian who was in a crosswalk was \$103, regardless of the severity of the injuries. In 2000, the fine was increased to \$594, an amount that is still ridiculed by pedestrian safety groups. British Columbia was charging a \$144 fine for "failing to yield to a pedestrian." Wisconsin was levying penalties of \$20 to \$300 for pedestrian-related violations. Higher fines were associated with two or more

convictions for the same offense, illegally passing a school bus, and not obeying school crossing directions.

Lightstone et al. (1997) found that drivers who hit a child pedestrian were more likely to have had a prior citation, several citations, a suspended or revoked license, negligent driver “points,” or more safety violations than drivers who had not hit a child pedestrian. The authors recommended that one intervention would be more rigorous sanctions against the drivers, including higher monetary and insurance penalties, and the vigorous pursuit of unlicensed and hit-and-run drivers. Marosi and Herndon reported on the extreme point of view of John Pucher, urban planning professor at Rutgers University, who stated “motorists are literally getting away with murder in the U.S., and the result (*i.e., a lack of severe penalties*) encourages more and more dangerous driving.” Earlier, Haight and Olsen (1981) suggested that driver behavior “seems to reflect the level of enforcement rather than the text of the law.”

Portland, Oregon. Oregon’s vehicle code features a chapter on “rules of the road for drivers.” The following driver actions represent violations of Oregon state law:

- Failure to stop and remained stopped for a pedestrian in a crosswalk
- Passing a stop vehicle at a crosswalk
- Failure to yield to a pedestrian on a sidewalk
- Failure to stop and remained stopped for blind pedestrians
- Failure to stop for a pedestrian proceeding under a traffic control device
- Failure to stop for a pedestrian when making a turn at a stop light

A number of Oregon statutes apply to pedestrian duties. Information was unavailable on the magnitudes of the fines for the preceding violations.

Florida. The state assigns points to drivers for various infractions. Passing a stopped school bus is associated with 4 violation points, making this activity among the most serious infractions. Otherwise, pedestrian-related infractions by drivers are not associated with violation points.

New Jersey. The state penalty schedule assigns two points for “failure to yield to pedestrian in crosswalk,” and for “passing a vehicle yielding to pedestrian in crosswalk.” Actual fines are determined by “the courts.”

Washington. The penalty and bail schedule for highway user infractions is provided by the Washington State Patrol Troopers Association. Fines are levied for both driver and pedestrian violations. For drivers, passing a vehicle stopped at a crosswalk is subject to a \$101 fine. Any collision that occurs in conjunction with this regulation raises the fine to \$153. For pedestrians, “suddenly entering the roadway” is subject to a \$46 fine; walking behind a vehicle that is stopped at a crosswalk is subject to a \$101 fine. A \$46 fine also applies to a number of other pedestrian violations, including failing to obey a pedestrian signal or walking in the roadway when there is a sidewalk.

Discussion. As mentioned above, driver citations on the PARs reviewed for this research pertained to the motor vehicle infraction, rather than the collision with the pedestrian. A common driver statement was “I did not see the pedestrian,” implying that the pedestrian was performing an improper crossing. Further, if a pedestrian was severely injured or killed, there was no way to get the pedestrian’s story, thereby biasing the crash report toward the driver’s statements. Exceptions to this rule were evident when the driver was intoxicated – then, the driver was typically charged with being under the influence. Marosi and Herndon (1999) found that some California police officers were confident that steeper fines would have an impact on driver behavior in the vicinity of pedestrians. The authors noted that driver penalties for hitting pedestrians were much more severe in Europe than in the U.S., and that pedestrian injury rates were

lower. The question of “what is the appropriate penalty” for a driver in a pedestrian-vehicle incident is challenging to answer. A determination of the person at fault would seem to be the right approach, but this is often difficult to ascertain – particularly if the pedestrian is severely or fatally injured. Further, errant pedestrian behavior may be associated with a lack of adequate pedestrian facilities. A pedestrian may need to walk in a roadway or cross at an unmarked location because no other facilities are available. One approach would be to withdraw from attempting to determine who was at fault. That is, establish a “mea culpa” policy in which the driver must assume the costs (or some portion of the costs) of the injuries to the pedestrian, or those associated with a fatality. Such a policy could, perhaps, encourage an increase in hit-and-run incidents; this would be a subject for further research.

Flowers and Beach (2002, and previous years) report annually on Utah’s highway crash statistics. Between 1997 and 2002, a total of 4,370 drivers were involved in pedestrian-vehicle crashes (it is not known if any of these were the same driver!). A total of 1,726 citations were issued to the drivers. A total of 55 of the drivers fled the scene (hit and run). So, of the 4,315 drivers who *could* have been cited, only 40% were actually issued a citation. The most “popular” citations were failure to yield right of way (822 or 47.6%), improper lookout (275 or 15.9%), a non-moving violation other than improper lookout (165 or 9.6%), driving under the influence (38 or 2.2%), and speeding (33 or 1.9%). Typical non-moving violations would include lack of proof of insurance or malfunctioning headlights or taillights. (Non-moving violations data were not reported in 1998). Also, between 1997 and 2002, a total of 199 drivers were involved in fatal pedestrian-vehicle crashes. A total of 36 citations were issued to these drivers. Two of the drivers fled the scene; so, of the 197 drivers who *could* have been cited, only 18.3% were issued a citation. These statistics are somewhat perplexing, and perhaps even disturbing, given the typically serious outcomes of pedestrian-vehicle crashes.

Example Guidelines. *Since this issue is related to enforcement and legislation, there are no specific engineering-related guidelines at this time. Enforcement and legislation must be recognized as essential ingredients in pedestrian safety improvement. One approach would be a statewide “mea culpa” policy in which the driver in a pedestrian-vehicle collision assumes the responsibility for all or a portion of the costs of the pedestrian’s injuries. The driver would be exempted from responsibility upon confirmation that the pedestrian was intoxicated or under the influence of drugs. Another approach would be to increase the severity of the penalties for violating pedestrian-related motor vehicle laws. These and other related strategies would need to be developed within the law enforcement and legislation communities.*

CHAPTER 7.0 Other Issues

7.1 Pedestrian Volume Data Collection and Usage

Problem Statement. Pedestrian volume data is fundamental to the analysis of pedestrian facility needs; the relationship between these two is similar to that between traffic volume data and highway facilities. That is, traffic volumes serve as inputs to the determination of highway capacity, traffic control strategies, traffic signal timing, grade separation, traffic management approaches, before-after safety analysis, and other needs. Pedestrian data are not regularly collected by jurisdictions in Utah, however. This is a gap in the traffic monitoring process that needs to be filled.

Literature Review. Lyon and Persaud (2002) found that pedestrian volume information produced a much richer model of pedestrian collisions at intersections than a model that used motor vehicle volumes only. The authors admitted that many jurisdictions did not have data sets containing sufficient pedestrian volume counts, though. Cottrell and Pal (2003) discovered that 75% of 60 state, regional and local agencies surveyed were collecting some pedestrian volume data. The data were generally not being used, though, in the development of pedestrian crossing mitigations.

Portland, Oregon. This subject is not discussed in the agency's guidelines.

Florida. This subject is not discussed in the agency's guidelines.

New Jersey. This subject is not discussed in the agency's guidelines.

Washington. This subject is not discussed in the agency's guidelines.

Discussion. Pedestrian volume data are being collected by transportation agencies, but the data are most commonly used in traffic signal warrant studies and intersection operations analysis. Many pedestrian crossing warrants refer to pedestrian volume criteria; in truth, however, the data needed to evaluate these warrants are often lacking. Further, there is little integration between pedestrian volumes and facilities. At the pedestrian-vehicle crash locations examined for this research, for example, there was no information on the local pedestrian volumes. In contrast, it was easy to find data on the motor vehicle volumes at these locations. A pedestrian counting program is in order, but there are few guidelines available for the development of such a program. Cottrell and Pal (2003) recommended the development of a pedestrian traffic monitoring guide as a companion to the *Traffic Monitoring Guide* for motor vehicles. The author is not aware of a current or planned effort to develop a pedestrian monitoring guide.

Example Guidelines. *In the absence of a pedestrian traffic monitoring guide, the interim approach would be to develop a pedestrian counting program that is based on pedestrian-vehicle crash sites. The counting locations could mirror those that have been the scene of recurring pedestrian-vehicle crashes. Since many of these locations are geographically close together, it would be prudent to conduct counts along corridors that featured recurring pedestrian-vehicle crashes between 1992 and 2001.*

Count Locations. *A study by Espino et al. (2003) of pedestrian-vehicle collisions in Florida determined that a crash frequency of three per year per mile was high. An application of this criterion to Utah's 1992-2001 pedestrian-vehicle crash locations revealed **eight** recurring pedestrian-vehicle crash corridors. A pedestrian volume counting program should be implemented along these eight corridors; a more comprehensive count program should be developed following the release of further guidance on pedestrian volume monitoring.*

Table 7. Recurrent Pedestrian-Vehicle Crash Corridors (3 crashes/mi/yr: 1992-2001)

City	Route	Name	Milepost & Endpoint	Milepost & Endpoint	Length	Crashes
Logan	A00091	Main St	26.16 – 300 South	27.22 – 500 North	1.06	36
Murray	A00089	State St	320.05 – Constitution	327.68 – N. Temple	7.63	257
South Salt Lake		North Temple	327.68 – State St	328.28 – 300 West	0.60	14
Salt Lake City		300 West	328.28 – N. Temple	329.31 – 800 North	<u>1.03</u>	<u>10</u>
					9.26	281
Ogden	A00089	Washington Bl	354.05 – Goddard St	355.44 – 23 rd South	1.39	42
Salt Lake City	351350	200 South	0.21 – e/o 200 West	1.20 – 500 East	0.99	36
Salt Lake City	351355	West Temple	0.01 – 400 South	0.65 – Temple Square	0.64	35
Salt Lake City	A00186	North Temple	2.81 – 1300 West	4.30 – 300 West	1.49	43
		300 West	4.30 – North Temple	5.04 – 400 South	0.74	34
		400 South	5.04 – 300 West	7.17 – Koneta Ct	<u>2.13</u>	<u>58</u>
					4.36	135
South Salt Lake	A00171	3300 South	10.11 – 300 West	11.01 – 300 East	0.90	31
Taylorsville	A00068	Redwood Rd	51.72 – 5245 South	54.03 – 3800 South	2.31	67
West Valley						
TOTAL					20.91	663

Two of the eight corridors – US 89 in Salt Lake County and SR 186 in Salt Lake City – incorporate three roads apiece, such that the eight recurrent corridors include twelve different road segments. The lengths of the segments range from 0.64 to 7.63 miles. A total of 663 pedestrian-vehicle collisions occurred along these corridors between 1992 and 2001, representing 7.5% of the State's 8,838 pedestrian-vehicle collisions. Additional pedestrian-vehicle crashes occurred at some of the cross-streets along the recurrent corridors; the numbers above do not include the cross-street crashes.

Pedestrian-vehicle crashes occurred at regular intervals along the recurrent corridors, with clusters at intersections, and intermittent midblock collisions. Counts should be conducted at intersections (two crossings of the corridor per intersection) and at midblock locations where collisions have occurred. Further study is suggested to select the count locations.

Count Times, Duration and Frequency. Little guidance exists as to when, how long, and how frequently pedestrians should be counted. The analysis of Utah's 1992-2001 crash data indicated that peak pedestrian-vehicle collision periods occurred during the afternoons and evenings of Fridays during October. One approach, then, would be to conduct annual pedestrian volume counts along the eight corridors during the following periods:

- October
- Friday
- 2:30-10:30 PM (peak 8-hour period) OR
- 4:00-8:00 PM (peak 4-hour period; with 5:30-7:30 PM as the peak 2 hours, and 5:30-6:30 as the peak hour)

The longer 8-hour data collection period would provide some useful nighttime pedestrian activity information. Pedestrians can be counted manually in the field, manually from videotape, or by pushbutton activations. An alternative approach would be to establish permanent pedestrian counters at selected locations. Pedestrian sensors based on a variety of technologies have been developed. Further study is suggested of these technologies to determine their usefulness in a pedestrian counting program.

7.2 Pedestrian Visibility Enhancement

Problem Statement. About 42% of Utah's 1992-2001 pedestrian-vehicle collisions occurred at night (between 5:30 PM and 6:30 AM from November through March, and between 7:15 PM and 6:30 AM from April through October). It is likely that the number of nighttime pedestrian-vehicle collisions is not commensurate with the amount of nighttime walking. It is not possible to confirm this supposition, though, because information is not available on pedestrian volumes by time of day. Using rich data sets from other areas, however, researchers have confirmed that pedestrian-vehicle crash rates are indeed greater at night than during the day.

Literature Review. Smeed (1977) argued that pedestrian-vehicle incidents were ten times more likely to occur at night than during the daytime, when adjusting for the distance walked. Reinhardt-Rutland (1986) suggested that reflective clothing may not effect the desired reduction in pedestrian-vehicle crashes at night, because of the presence of other factors. One key factor is the driver's potential misperception of distance at night because of reduced visual information; the effect may be directly related to the driver's own myopia. Shinar (1985) reached a similar conclusion, reporting that drivers in nighttime tests responded to the presence of a pedestrian who was wearing a retroreflective tag only when there was prior knowledge of the association between the tag and a pedestrian. These authors' findings indicate that artificial lighting may be the surest tool to improving pedestrian safety at night. Polus and Katz (1978), for example, found that crosswalk illumination and signing were associated with a significant reduction in nighttime pedestrian-vehicle crashes. Mortimer (2001) indicated that the visibility of pedestrians at night is affected by the reflectance of their clothing, their position in the roadway, atmospheric conditions, road characteristics, street lighting, motor vehicle headlamp aim, alignment and brightness, other ambient lighting and background conditions, glare from the headlights of oncoming traffic and street lamps, the driving environment, and the activities and performance of the driver.

Portland, Oregon. Pedestrian visibility is not explicitly discussed in this agency's guidelines.

Florida. Pedestrian visibility is not explicitly discussed in this agency's guidelines.

New Jersey. Illumination should be considered as warranted when the nighttime visibility requires lighting in order to provide the mutual sight distance capabilities described in AASHTO policy. Specific situations at which a crosswalk and illumination should be considered include:

- The roadway has a speed limit greater than 65 KPH (40 MPH) and does not provide adequate pedestrian conflict elimination.
- Intersections, access locations, decision points, and areas adjacent to changes in roadway alignment and (or?) cross-section.
- Areas adjacent pedestrian generating centers and parking lots.
- Refuge islands, particularly at approach ends, barrier curbs, and other median structures.
- Any location where problems associated with nighttime visibility have led to frequent pedestrian-vehicle conflicts.

Sidewalks are to be provided with at least 0.2 footcandles (fc) or 2 lux in residential areas, at least 0.6 fc (6 lux) in "intermediate" areas, and at least 0.9 fc (10 lux) in commercial areas. Pedestrian paths are to be provided with at least 0.5 fc (5 lux) in residential areas, 1.0 fc (11 lux) in "intermediate" areas, and 2.0 fc (22 lux) in commercial areas. Crosswalks traversing roads midblock should be provided with illumination that is 1.5 to 2 times the normal roadway lighting level.

Washington. Lighting of between 0.5 and 2.0 fc of illuminance is to be provided along pedestrian travel ways, “depending on conditions.”

Discussion. Pedestrian visibility is multi-factorial, with dependence on the pedestrian’s clothing, the driver’s alertness, the driver’s nighttime visual acuity, the roadway and driver environment, and street and ambient lighting. Street lighting is only one of the factors, although the lighting provided can affect the other factors. Illuminance criteria, such as those used in New Jersey, are directed more specifically at the pedestrian than the driver. That is, illuminance, since it is a measure of the reflectance of light, is a measure of how well a pedestrian can see the surrounding walking surfaces and environment. Standards have recently been developed for small target visibility (STV). The STV is measured in terms of visibility level (VL), which is the ratio of small target luminance to background luminance. If the “target” is a pedestrian, then VL could be used to assess the visibility of pedestrians against various backgrounds. The luminance of the pedestrian is subject to wide variation, though, given the different levels of reflection of clothing. The new STV standards have been established for a small, 18 cm x 18 cm, diffuse object having 50% reflectance, and the visual acuity of a typical 60-yr old driver having a 0.2-sec fixation time. It is likely that the clothing of many pedestrians does not provide 50% reflectance; therefore, it is not certain that the STV standards are generally applicable to pedestrians. Further research is needed on visibility standards for pedestrians.

Example Guidelines. *Local jurisdictions throughout Utah have established street lighting criteria. In some cases, these criteria may need to be updated to reflect the most recent recommendations of the Illuminating Engineering Society of North America (IESNA), as released in 2000. Criteria should be in place for luminance and illuminance. New Jersey’s pedestrian facility illumination guidelines are an example of those that should be in place. Consideration should be given to adopting the IESNA’s standards for small target visibility, if such action has not yet been taken. The IESNA standards for small target visibility (STV) are listed in Table 8. The STV criteria assume that the luminance criteria listed are met.*

Table 8. Small Target Visibility Criteria (Illuminating Engineering Society of North America)

Road	Pedestrian Activity	STV Criteria	Luminance Criteria		
		Average Visibility Level	Average Luminance		Uniformity Ratio
			Median < 7.3 m	Median ≥ 7.3 m	
			L_{avg}	L_{avg}	
Major	High	4.9	1.0	0.8	6.0
	Medium	4.0	0.8	0.7	6.0
	Low	3.2	0.6	0.6	6.0
Collector	High	3.8	0.6	0.5	6.0
	Medium	3.2	0.5	0.4	6.0
	Low	2.7	0.4	0.4	6.0
Local	High	2.7	0.5	0.3	10.0
	Medium	2.2	0.4	0.3	10.0
	Low	1.6	0.3	0.3	10.0

NOTES: Average criteria are measured over the designated study area. “Median” refers to the width of a roadway median. VL is a dimensionless ratio of target to background luminance. Luminance is measured in cd/m^2 . The uniformity ratio is the maximum value of the ratio of the maximum to minimum luminance in the study area.

Definitions of “high,” “medium,” and “low” pedestrian areas need to be established; statewide definitions would ensure consistency between different jurisdictions. It is unknown if the STV criteria have been adopted by agencies in Utah. Studies of pedestrian activity by time-of-day are needed to better understand pedestrian activities at night. Further study is also needed of the applicability of the STV criteria to motorist visibility of pedestrians at night.

7.3 School Zones and Child Pedestrians

Problem Statement. Most child pedestrian-vehicle incidents occur outside of school zones during non-school hours (Jordan 1998). Since school zones can be “safe havens” for child pedestrians – at least during school access hours – it is possible that school zone *size* may be related to child pedestrian safety. School zones offer protection to child pedestrians within a limited area, though. In 2002, 46.2% of all pedestrian-vehicle crashes in Utah involved a child or teenager under age 20 (Flowers and Beach 2002). Nationally, the pedestrian involvement rate for children and teenagers aged 20 and under was about 27% (*Traffic Safety Facts 2002*). The indication is that child and teenage pedestrian involvement in collisions with motor vehicles in Utah is greater than the national average.

Literature Review. Child pedestrians have been extensively studied in the engineering and medical literature. Howarth et al. (1974) sought to find causal explanations for the number of crashes involving child pedestrians in England. Year 1966-1968 data from 30 MPH speed limit areas indicated that boys aged 3 to 9 were involved in between 500 and 800 crashes per year. Girls in the same age group were involved in 250 to 400 crashes per year. Below age 3 and above age 9, both boys and girls were involved in 50 to 200 crashes per year. Field studies revealed that the number of roads crossed per day ranged from 3.5 for children aged 5 to 8, to 10 for children aged 10. The number of vehicles encountered per day ranged from 0.1 for children aged 5, to 0.3 to 0.6 for children aged 9 and 10. An “encounter” was defined as occurring only when the child exhibited “heedless” behavior. Based on interviews of children of various ages, the writers determined that the risk per road crossing, and the risk per vehicle encounter, steadily decreases from age 5 to age 10, with boys at greater risk than girls. The risk levels were adjusted based on whether or not the child was accompanied, and on how the child behaved at crossings.

In an in-depth study of pedestrian injuries in Memphis, Tennessee during 1982, Rivara and Baker (1985) found that there were 210 pedestrian injuries among children aged 0 to 14 years. This represented a rate of 138 per 100,000 children. The injured child was most often male, with an average age of 7.3 years. The child was most commonly struck while crossing midblock, usually between 2 and 7 PM. The child pedestrian injuries were distributed among 81 of Memphis’ 142 census tracts. Compared to the other tracts, the 81 tracts typically had low household incomes, a large number of nonwhite households, a large number of female-headed households, and a large number of persons per household. In a regression analysis, the variable “crowded housing per acre” was the best predictor of the number of child pedestrian injuries per acre. The authors suggest that traffic engineering-related modifications, targeted toward environments in which pedestrians have high levels of exposure, would be a practical strategy. Similar results were obtained by Pless et al. (1987) in a study of crashes in Montreal, Quebec. Further, drivers under age 20 were associated with the highest rates of severely injured pedestrians. Severe child pedestrian injury was also associated with vehicles heading straight (as opposed to turning vehicles) and with vehicles other than cars. The authors also found that the pedestrian injury rates for boys aged 10 to 14 and girls aged 5 to 9 in Massachusetts were twice those of similar age groups in Montreal. The authors attributed the difference to a higher portion of teenage drivers in Massachusetts. (The difference might also have been partially attributable to the inclusion of rural areas of Massachusetts in the pedestrian injury rates). Similar results to those of Rivara and Baker (1985) and Pless et al. (1987) were obtained by Dougherty et al. (1990) and Braddock et al. (1991), who argued that children living in low-income areas are more susceptible to pedestrian injuries than children living in well-to-do areas.

Tight (1988) analyzed the risk to child pedestrians during their journeys to and from school in five urban areas in England. Between 1979 and 1984, there were 670 child pedestrian injuries within the five areas. Of these, about 26% occurred during the journey to and from school. More children tended to walk from than to school, and girls tended to be accompanied more frequently than boys. Also, children tended to walk farther on the way home than on the way to school. Secondary school children were accompanied the least frequently, and walked farther and for a greater time period than primary school children. The risk of a crash was determined to be greater during the walk home than during the walk to school. The risk of a crash was twice as high within 500 meters of a school as at distances greater than

this. Crash risks were three times greater at crossings that had no provisions than at crossings with facilities.

Recognizing the important role of parents in child pedestrian safety, Rivara et al. (1989) conducted a survey of parents living in a suburban area of Seattle, Washington. A total of 2,464 surveys of parents of children in grades kindergarten to four were returned. A total of 94% of the parents did not think that 5 and 6-year olds can reliably cross streets alone. One-third of the parents, however, allowed kindergarten-aged children to cross residential streets alone and let first-grade children walk to school alone. Only 17% of the parents believed that children should be taught *not* to cross the street alone, and 50% of the parents believed that children should be taught how to cross busy streets at unsignalized locations. The authors surmised that parental expectations of their children may be inappropriate, and that parents may be an appropriate target for injury-prevention programs. Similar results were reached by Dunne et al. (1992). These authors found that parents overestimated the abilities of their children in tests of street-crossing skills. The parents' expectations were least accurate for 5 to 6 year old children, but the mismatch decreased as the age of the child increased.

Roberts (1993) discussed the reasons behind declining child pedestrian death rates in Great Britain. He noted that, in England and Wales between 1968 and 1987, pedestrian mortality for children aged 0 to 4 years fell by 67%, while that for children aged 5 to 14 fell by 39%. The author argued that neither prevention programs nor improvements in medical care were plausible explanations for the decline. Rather, the decline was most likely the result of a substantial reduction in the children's exposure to traffic. He noted that one study found that 80% of 7 and 8 year old children traveled to school alone in 1971; that figure had dropped to just 9% in 1990.

Bass et al. (1992) reported that 60 to 70% of child pedestrian injuries occur within 2 km of the child's home, usually when the child darts out into the street without warning. The authors interviewed the parents of 154 children under age 15 who had been injured in a pedestrian crash. All 154 children had been treated at the Red Cross Children's Hospital on the Cape Peninsula of South Africa. A total of 84% of the crashes had occurred in the child's neighborhood, and 42% had occurred just outside the child's home. A total of 90% of the incidents had occurred during the day, mostly between 3 and 7 PM. At the time of the collision, 69% of the children had been either playing or running errands. Only 35 (23%) of the kids were being supervised by an adult at the time of the collision. The authors concluded that many children choose the street as their playground, and that it may be difficult for parents to be around to supervise during the afternoon. The authors suggest that various methods for redirecting or prohibiting motor vehicle traffic on certain streets during late afternoon hours be investigated.

Agran et al. (1994) reviewed the injuries to 345 child pedestrians (under 15 years of age) which occurred in Orange County, California between 1987 and 1989. The children were treated at one of nine local hospitals. The authors computed the following distribution of the location of injury along with the corresponding median age of the injured child:

- 11%: in driveways (median age: 2 years),
- 8%: in parking lots (median age: 4 years),
- 53%: at midblock (median age: 6 years), and
- 28%: at intersections (median age: 10 years).

It is evident that small children tended to be involved in off-street pedestrian crashes, while older children's incidents involved street crossing. Midblock crashes might involve either street crossing or darting out. The authors suggested that street-crossing training may have little impact on a child's playing activities, during which he or she may dart out. The authors noted that a substantial portion of the midblock crashes involved preschool children, none of whom had been exposed to formal pedestrian safety training. Interventions for nontraffic locations might include backup warning devices and improved mirrors (or other visual aids) that allow the driver to see directly behind his or her vehicle.

Roberts et al. (1995) confirmed that exposure to traffic is strongly associated with the risk of injury to child pedestrians. The authors studied the locations at which 190 child pedestrians were either killed or hospitalized following a motor vehicle collision. The setting was the Auckland region of New Zealand. The authors found that the risk of injury was 14 times greater at high-volume sites than at the least busy sites. Also, a high density of curb parking was associated with an increased child pedestrian injury risk. Higher risks were associated with average speeds of over 40 KPH than at lower-speed sites. The risk of injury did not continue to increase with increasing average speed, however. The authors suggested that attention to both speeds and curb parking may be effective in reducing rates of child pedestrian injury and mortality.

Rao et al. (1997) examined children's exposure to traffic in Baltimore, Maryland during 1993. Using a survey methodology, in which 861 of 3,285 survey forms were returned from participating schools, the authors determined that there was a wide variation in the number of streets crossed per day among the children. For children whose parents owned both a car and a home, an average of 3.7 streets per day was crossed. An average of 5.4 streets per day was crossed by children whose parents did not own both a car and a home. A significant correlation was found between the proportion of children who are driven home from school and the rate of child pedestrian injury in different regions of Baltimore. That is, pedestrian injury rates were significantly lower in regions in which many children were driven home. Pedestrian injury rates were highest in regions with low car and ownership. The authors emphasized that interventions must be adapted to the child's environment. They suggested that a change in the child's environment might prove more effective than attempting to change the child's behavior.

Macpherson et al. (1998) conducted a similar study to Rao et al. (1997) using data from 2,501 children attending 50 schools in Montreal, Quebec. The authors found that the peak pedestrian injury rate occurred for children between ages 6 and 8 years. The injury rate for boys was consistently higher than that for girls. The average number of streets crossed per day was found to be strongly associated with the corresponding injury rate. The mean number of streets crossed per day ranged from 3.8 for children aged 5 to 6 years to 6.6 for children aged 11 to 12 years. About 12% of all children in 1st grade walked alone from school, compared with about 23% of 4th grade children. About 59% of all 1st grade children walked from school (most were accompanied), while about 64% of all 4th grade children walked. The authors noted that exposure to traffic explains the variation in pedestrian injury rates, but it does not explain gender or age-specific differences. For example, though older children were more exposed to traffic, younger children were at greater risk for pedestrian injuries. As found in other studies, children living in disadvantaged areas of the city crossed up to 50% more streets per day than children living in middle and upper income areas. A correlation was observed between the mother's level of education and the number of streets crossed by the child per day. The authors proposed that intervention focus on the environment rather than the potential victim. Targeting the victim, they argue, puts an added burden on the parents to accompany their kids to and from school, and possibly encourages reduced outdoor activity.

Portland, Oregon. A school speed zone can be established in Oregon under the following conditions:

- The posted speed limit in the zone does not exceed 35 MPH.
- The roadway is contiguous to a property that houses a full-time public or private school.
- There is at least one marked school pedestrian crossing that is part of the school's safe route to school plan.
- The school provides K-8 instruction.
- An engineering study supports the establishment of a school speed zone.

Further justification for a school speed zone is required if the speed limit exceeds 35 MPH, the roadway is not contiguous to a school property, high school instruction is provided, a marked school crossing is located away from the school grounds, or students do not typically cross the subject roadway. School speed zones are discouraged where the posted speed limit is 45 MPH or greater. A school advance

warning sign may be established regardless of the establishment of a school speed zone. An engineering study is to consider the location's crash history, traffic volumes, gaps between vehicles, the number of bicyclists riding to school, pedestrian volumes, motor vehicle speeds, sight distances, the safe route to school plan, and community and school district input. Once a school speed zone is established, it is to extend from 100 to 200 ft upstream and downstream of the school property.

Florida. Crossing guards are to be stationed at uncontrolled crossings within 180 m (600 ft) of the school.

New Jersey. Provide a crosswalk at all "locations" within 400 m of a school.

Washington. State law is that the school speed limit zone extend for 300 ft upstream and downstream of a school crossing. The school zone speed limit is 20 MPH.

Discussion. The findings in the literature suggest that child pedestrian safety interventions that focus on the environment may be more effective than education and training. Engineering-related strategies, therefore, may be critical in improving child pedestrian safety. The findings are also that more child pedestrian incidents occur outside of school zones than inside. The strategies, therefore, must be broader than those that pertain to school zones. The concentration of child pedestrians within school zones warrants, nonetheless, their special treatment.

The Utah Administrative Code designates UDOT and local transportation agencies as the authorities responsible for establishing reduced speed school zones. Speed zones at elementary schools *must* be established, while speed zones at secondary schools *may* be established upon request by the local authority. School zones are in operation when children are going to or leaving, and a crossing guard must be present at all elementary schools. School zone speed limits are 20 MPH, and their application is indicated by flashers installed at all entrances to the zone.

The UDOT publication *Traffic Controls for School Zones* (UDOT 2003) describes the criteria used to designate reduced speed school zones. The establishment of a zone is based on a system in which points are assigned for the average time between usable gaps between motor vehicles, the school pedestrian volume, the 85th percentile approach speed, and the average child pedestrian demand per gap. Once a reduced speed school zone is warranted, local conditions are used to establish the actual boundaries of the school zone. The guidance is that the upstream boundary be located "as near as practical to the required distance from the school crosswalk," and the downstream boundary be located "as near to 50 ft as practical on the far side of the school crosswalk or...intersection." The "required distance" ranges from 150 to 250 ft, depending on the speed limit upstream of the school zone.

There is quite a bit of variation between the agencies studied for this research on the size of school zones. The school zone limit and employment of crossing guards can extend from 100 ft (Oregon) to 600 ft (Florida). It is evident that the size of a school zone should be based on a number of inputs, including traffic volumes, speeds, pedestrian volumes, and others. The research team was unable to identify a common set of criteria for setting school zone boundaries. Based on the findings of Jordan (1998), an investigation of the feasibility of expanding school zones may be worthwhile. Such a study, which was also including an examination of school access routes, was under way at press time.

There is little discussion in the literature of engineering-related solutions to child pedestrian safety improvement outside of school zones. The strategies mentioned include child pedestrian safety education, pedestrian safety education for parents, curb parking restrictions, and enforcement of motor vehicle laws. Signing and traffic calming strategies probably represent the most appropriate mitigation, particularly in neighborhoods and along school access routes. A full investigation of traffic calming strategies – and their impact on pedestrian safety – was beyond the scope of this research.

Example Guidelines. *Reference is made to Ewing (1999), who suggested that traffic calming be implemented on local residential streets when the:*

- *Traffic volume exceeds 1,000 per day or 100 per hour*
- *Anticipated neighborhood cut-through traffic equals 25% of current volumes*
- *85th percentile speed exceeds the speed limit*
- *Majority of the neighborhood residents concur with the implementation of traffic calming*
- *Pedestrian crossing volumes exceed 25 per hour*
- *Number of pedestrian-vehicle crashes has averaged three or more per year*

The anticipated cut-through traffic refers to the amount of diversion to other streets after the implementation of calming. The latter criterion should apply to a well-defined neighborhood rather than an individual street. Similarly, pedestrian crossing volumes should apply to a defined segment of road rather than an individual crossing. For collector streets, the following criteria apply:

- *Traffic volume exceeds 8,000 per day or 800 per hour*
- *Anticipated neighborhood cut-through traffic equals 50% of current volumes*
- *85th percentile speed exceeds the speed limit plus 10 MPH*
- *A majority of neighborhood residents concur with the implementation of traffic calming*
- *Pedestrian crossing volumes exceed 100 per hour*
- *Number of pedestrian-vehicle crashes has averaged six or more per year*

Consider the following traffic calming strategies, each of which has been associated with improvements in street user safety in residential areas:

- *Speed humps (not recommended on collectors or primary emergency response routes)*
- *Left and right turn restrictions*
- *Conversion to one-way streets*
- *Chokers*
- *Raised medians and median barriers*
- *Channelization*
- *Diverter*
- *Cul-de-sac street designs with connecting pedestrian-bicycle paths*

In addition to these strategies, continue to aggressively implement all relevant school zone and child pedestrian safety plans, criteria, educational programs, and enforcement practices.

CHAPTER 8.0 References

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